Amy Lynn Fletcher

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Biotechnology and the Future of Extinction

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To Bill and Sandra for everything and to Bosley and Budo, just because

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Chapter 1
The Future of Extinction

Abstract As the global extinction crisis accelerates, conservationists and policy makers increasingly draw upon advanced biotechnologies such as reproductive cloning, polymerase chain reaction (PCR) and DNA barcoding in the urgent effort to save species. This book considers the ethical, cultural and social implications of using these technoscientific tools for wildlife conservation. Drawing upon sources ranging from science to mass media to literature, I focus on the stories we tell about extinction and the meanings we ascribe to nature and technology. These narratives, far from being ephemeral to either politics or conservation, embody our fears and dreams about the future of nature and our place within it. Our increasing reliance on biotechnological tools is a matter of practical consequence, but also a platform for constructing a futuristic wilderness repopulated with such wonders as Tasmanian tigers, mammoths and moas. Biotechnology thus shapes the wildernesses we can envision and affects which species are likely to survive and even those which might one day be revived. This chapter begins with the story of the first known marine mammal to vanish in the twenty-first century, the Yangtze River dolphin, and then introduces the major themes and research questions of this book. The chapter concludes with a preliminary discussion of the emerging discourse of de-extinction.

> *The idea is now hovering before me that man himself can act as creator even in living nature, forming it eventually according to his will.*
>
> –Jacques Loeb, letter to Ernst Mach, 26 February 1890 (Pauly 1987)

1.1 Goodbye to the Baiji

While politicians and scientists argued its fate, the Yangtze River dolphin (*Lipotes vexillifer*, also known as the baiji) disappeared sometime in the early twenty-first century. Scientists and conservationists had known for at least two decades that the baiji was critically endangered. The species had been declared one of the most endangered on the planet in 1986, when a population of approximately 400 river dolphins still survived. Approximately a decade later, in 1997, an official survey of the Yangtze River in China counted only thirteen dolphins. Acknowledging the pending catastrophe, the Chinese Ministry of Agriculture finally approved an *Action Plan for Cetaceans in the Yangtze River* in 2001, though three years later the plan

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had not been implemented, due primarily to a lack of funding. In late 2004, the Institute of Hydrobiology in Wuhan, China, hosted an international workshop on the urgent need to develop conservation plans for both the baiji and the Yangtze finless porpoise. Even at this late date, scientists spent much of the meeting vigorously debating whether the remaining baiji should be moved to a dolphinarium or to a semi-natural reserve, though all agreed "a decision not to remove the baiji from the Yangtze carries a risk that the species—which represents an entire family—will go extinct because of the ongoing, and increasing, threats in its natural environment" (Braulick et al. 2005). In December 2005, the Zoological Society of London, in association with the Baiji.org Foundation and the Chinese Ministry of Agriculture, developed an emergency conservation plan that optimistically included projected publication by 2009 of a peer-reviewed article on baiji recovery as one of the key research outputs (International Union for Conservation of Nature 2006).

Yet in 2006, a major 6-week, six-nation expedition along the Yangtze River, organized by the Wuhan Institute of Hydrobiology and the baiji.org Foundation (Switzerland), yielded no sightings, leading scientists and activists to conclude that the baiji was extinct (Turvey et al. 2007). Experts noted that a few animals may have been missed in the survey and grainy footage of what might have been a lone baiji appeared in 2007 on the Internet, raising international hopes that the species might yet have survived. Yet even if one or two animals endure, the species' fate is certain: the baiji seems unable to adapt either to the now extremely degraded river or to large-scale industrial fishing and dam construction. Even if a few remaining specimens survive and could mate in captivity (an open question), not enough genetic diversity remains to generate a viable, self-sustaining population. August Pfluger, Head of the baiji.org Foundation, concludes, " 'we have to accept the fact that the Baiji is functionally extinct. We lost the race. It is a tragedy, a loss not only for China, but for the entire world. We are all incredibly sad' " (China Daily 2006).

1.2 Hello to the Anthropocene

The baiji was known in pre-industrial China as the Goddess of the Yangtze. Its demise is the first official extinction of a large vertebrate in more than 5 years and the fourth disappearance of an entire mammal family since AD 1500 (Turvey et al. 2007). It is also the first cetacean known to have vanished as a direct result of human impact. The baiji's extinction is both a scientific and moral tragedy, but it is important to realize that this tragic narrative is a relatively recent one. To refer to it in this way imposes an interpretation on an event that, in the late nineteenth century, might as readily have been cast as an allegory of the inevitable triumph of industrialization over nature or as confirmation of the inexorable natural laws recently illuminated by Charles Darwin. As Charles Lyell argued in 1832, 27 years before the publication of Charles Darwin's *On the Origin of Species* brought the theory of evolution by natural adaption into the cultural mainstream, "amidst the vicissitudes of the earth's surface, species cannot be immortal but must perish, one

after another, like the individuals which compose them. There is no possibility of escaping from this conclusion" (Lyell 1832). Contemporary biologists use the term "background extinction rate" to refer to the normal processes of the modification of one species into another and the displacement of some species with better adapted competitors; moreover, as Norman MacLeod reminds us, extinction "is one of the most common of all ecological-evolutionary processes [and] represents the inevitable corollary of evolution via natural selection" (MacLeod 2005, p. 74). Indeed, the rich biodiversity we now cherish depends upon the slow but constant churn in species and their traits over geological time. The fact that we are better able than previous generations to document extinction via the tools of social media and science does not, by itself, necessarily mean that every final disappearance of a species is a tragedy.

Yet what happened to the baiji had almost nothing to do with the normal background extinction rate. It finally vanished because of such uniquely human activities as large-scale fishing of the river, indiscriminate use of fishing nets, illegal use of electric nets, habitat degradation, noise pollution, chemical pollution and anthropogenic climate change. Even deliberate political persecution played a part, as Chairman Mao encouraged slaughter of the baiji in the 1950s as part of the Communist Party's efforts to destroy spiritual beliefs among a peasant Chinese population that venerated the river dolphin. Its disappearance represents a significant and increasingly common event in a human-induced period of mass extinction so rapid and profound that some scientists argue that the Holocene (which began approximately 11,500 years ago) is over and the earth has entered a new period called the Anthropocene, a term coined by the Dutch chemist Paul Crutzen in 2000. The premise is straightforward. In this new epoch, via such mechanisms as geo-engineering, genetic modification and reproductive technologies, "a long-held religious and philosophical idea—humans as the masters of planet Earth—has turned into a stark reality. What we do now already affects the planet of the year 3000 or even 50,000" (Crutzen and Schwagerl 2011).

Currently, the Yangtze River supports an estimated ten percent of the world's population and is under intense environmental stress due to the Three Gorges Dam project, an iconic symbol of China's recent emergence as a global economic superpower and a testament to the energy needs such massive economic growth generates. Ultimately the baiji, a unique species that evolved over 20 million years, could not co-exist with the twenty-first century, despite the concerted last-minute efforts of Chinese scientists and international activist organizations to save it. The extinction of the baiji thus symbolizes a biodiversity crisis of stunning proportions and existential significance. We mourn its demise not only because of its unusual beauty and irretrievability, but also because we are fundamentally responsible and because of what its fate might portend for other species at the precipice of extinction, including, perhaps, our own. As Dr. Wang Ding, a member of the Chinese Academy of Science and a lead researcher on the 2006 baiji expedition warns, " 'If the Yangtze river cannot support the white-fin dolphin at present, maybe it cannot support human beings in the future. We must learn a lesson from it' " (Coonan 2006).

China, due to its breathtaking economic growth over the last 30 years, currently generates a high amount of media coverage about disappearing species, but the extinction crisis extends to every region of the globe and virtually every country. China's environmental crisis also parallels, albeit on a larger population scale, the earlier industrial era experiences of the United States, Australia, New Zealand and Europe. The rapid industrialization and urbanization of the Progressive Era (1890–1920) in the Western countries generated a new fear that wilderness and modernization might not be able to co-exist, while the mid-twentieth century saw the emergence of organized national environmental movements on a large scale. However, it is only in the late twentieth century that the slow end of the Cold War opened up a space for non-traditional security issues, such as climate change and the biodiversity crisis, to be considered significant enough to merit coordinated international action. The Convention on Biological Diversity (CBD), agreed at the Earth Summit at Rio de Janeiro in 1992, alongside the United Nations Framework Convention on Climate Change (UNFCCC), declared biodiversity a common concern of humankind and specified serious national and international biodiversity preservation targets to be met over the following decade. Today, not only are the targets not being met, but anthropogenic extinctions continue and the bad news arrives on almost a daily basis. *Time* magazine, for example, featured a cover story on the "New Age of Extinction" in April 2009, citing some scientific estimates that extinctions worldwide are occurring at a rate up to 1000 times greater than the normal background extinction rate that occurred prior to the emergence and proliferation of *Homo sapiens* (Walsh 2009). What distinguishes the current extinction epoch—what shifts it from being only a scientific or philosophical question, as in previous centuries, to a social problem and urgent public policy challenge as well— is the way in which human needs, technologies, policies and conflicts amplify the problem. As Crutzen and Schwägerl (2011) argue, "clumsily, we are taking control of Nature's realm, from climate to DNA. We humans are becoming the dominant force for change on Earth."

As with all things related to the environment, the concept of the Anthropocene is controversial. The International Commission on Stratigraphy created an Anthropocene Working Group in 2009 to consider whether or not the human impact on the environment is as profound and inexorable as the theory contends. Many philosophers and social scientists, furthermore, have long maintained that humans have never known nature in a pure and pristine sense that can be demarcated from culture. For example, philosopher Bruno Latour (2004) argued in his highly influential *Politics of Nature: How to Bring the Sciences into Democracy*, that "political ecology has nothing at all to do with nature, that blend of Greek philosophy, French Cartesianism and American parks" (p. 5). Though the scale of our impact and the types of technologies we use change over the centuries, the cultural turn in environmental studies has contended since the 1960s that the relationship between science and nature is forever being renegotiated (Latour 2004) and that there is no fixed boundary between science, culture and nature (Hellsten 2002). In the words of David Western, drawing "a sharp line between the human and the natural realms serves no purpose when our imprint is as ancient as it is pervasive" (Western 2001, p. 5458).

Yet in the worlds of public policy and conservation, drawing lines—between nature and culture, experts and laymen, between disciplines, between species, between the urban, the rural and the wild—remains essential to how we understand and manage the natural environment. To recognize that boundaries are permeable and culturally constructed does not make understanding them, and the social needs and anxieties that produced them, any less important. The metaphor of the Anthropocene, though it reifies the line between humans and nature, compels us emotionally because of the paradox that even if we are now the masters of the planet, we seem to be rapidly losing control of the unintended consequences of modernity. Yet while our technologies may be largely to blame for the environmental mess we now find ourselves in, they also seem to promise our last best chance to stop the Earth from hurtling towards a barren future. The idea of de-extinction, for example, refers to the possibility of literally reverse engineering an extinct species back to life via such tools as ancient DNA extraction and reproductive cloning. In its vision of an environmental past subject to scientific and biotechnological intervention, the de-extinction project represents not just a new concept or research agenda but a socio-technical imaginary, a vision of the environmental future that draws upon the past to compel and legitimize large-scale technoscientific interventions in the present (STS Research Platform 2012). To propose that biotechnology may someday allow us to undo the environmental damage we've done is to move from the twentieth century's environmental rhetoric of crisis to a new rhetoric of hope, to create a promissory wilderness which includes not only the species alive today but the multitude of species we thought irretrievably lost.

1.3 Wicked Problems and Socio-Technical Imaginaries

The search for biotechnological solutions is compelling in large part because the biodiversity crisis—and the associated problem of extinction—is the consummate wicked problem. In policy sciences, wicked problems are characterized by uncertainty and unpredictability, a plurality of perspectives and interests, complex problems of scale, cascading consequences and scientific uncertainty. Horst W. J. Rittel and Melvin M. Webber coined the term in the early 1970s, arguing that modern society increasingly faced problems for which science—designed to deal with "tame" problems that had clear boundaries—offered no decisive or de-politicized answers. In addition, "with wicked planning problems. . . *every* implemented solution is consequential. It leaves traces that cannot be undone and every attempt to reverse a decision or to correct for the unintended consequences poses another set of wicked problems, which in turn are subject to the same dilemmas" (Rittel and Webber 1973, p. 163). Writing in the United States in the early 1970s, against a backdrop of urban riots and political volatility, Rittel and Webber focused primarily on social problems. However, the wicked problem concept quickly became important in contemporary environmental studies, since it captured the complexities and value disputes that made straightforward solutions to such issues as climate change

or the extinction crisis exceedingly difficult to find and implement. In the case of the extinction crisis, even gathering data becomes a complex challenge since "estimates of the potential magnitude of modern extinction rates are fraught with error, assumption and politically inspired rhetoric" (MacLeod 2005, p. 80).

Increasingly, we try to take control of nature through the use of advanced technologies such as somatic-cell nuclear transfer (cloning), DNA bar-coding and in-vitro fertilization. Yet though such tools now contribute extensively to wildlife management, social scientific analysis of the evolving relationship between technology, society and the natural world is underdeveloped. Key questions that emerge in this new socio-technical space include: which species should be priorities for research and restoration using expensive technological methods and who should make these decisions? How does the use of such tools mediate our relationship to nature and wildlife? What are the environmental and cultural ramifications of reconceptualising life as a form of digital code? Perhaps most controversially, what are the realistic scientific and ethical limits of tools such as ancient DNA analysis and cloning with respect to resurrecting an extinct species? Despite the salience of such questions, social scientific analysis of the genomic revolution has tended to focus on such areas as human health and criminal justice rather than the environment. This book redresses this imbalance by analyzing four cross-cutting issues in the new world of techno-scientific conservation: (1) bioinformatics and the digitization of conservation; (2) reproductive cloning of endangered species; (3) ancient DNA analysis and prospective cloning of recently extinct species; and (4) the sequencing and analysis of DNA from long extinct species. It introduces these tools to an interdisciplinary audience and places them within the context of the development of the biotechnology industry and the biodiversity crisis (focusing on mammals).

The chapters in this book progress from the fundamental to the fantastical. Chapter two begins with an intellectual and cultural history of extinction in the Western tradition. Chapter three introduces the broad field of bioinformatics, illustrating the enduring influence of the life as code metaphor through analyses of the Encyclopaedia of Life project and DNA bar-coding. Chapter four analyzes the biomechanization of animal reproduction in the twentieth century, connecting the public furors over the Oncomouse and Dolly the Sheep with the new debate about the ethics of cloning highly endangered species. Chapter five considers the new field of ancient DNA analysis and the way in which it inevitably forces us to consider whether we could or should bring back recently extinct species, focusing on the Thylacine Cloning Project in Australia and on the Spanish Government's attempts to bring back the bucardo. Chapter six travels beyond the recent past to the dreamscape of deep time, prioritizing analysis of the idea that we might resurrect the woolly mammoth and other creatures from the Palaeolithic period. I neither contend nor try to prove that cloning a long extinct species like the woolly mammoth is feasible—that is a job for the molecular biologists and their colleagues. Rather, I focus on why this idea exerts such a strange fascination at this moment in time, on how it embodies our fears and fantasies about a future in which we will be able to conquer extinction and thus conquer death. The book concludes by reflecting on the de-extinction agenda

and on disruptive technological advances such as synthetic biology that may make it feasible.

This book draws upon 4 years of research including interviews with conservation and museum experts, archival analysis in libraries and museums in the United States and Australia (supported by funding from The University of Canterbury), and extensive document analysis of both scientific literature and mass media accounts of biotechnological conservation. Individually, the chapters reveal different policy issues and lessons, while collectively they demonstrate that our increasing reliance on biotechnology in conservation is reshaping the boundaries between the animal and the machine, the real and the artificial, and nature and culture. While each chapter illuminates specific aspects of technoscientic conservation in the Age of Biotechnology, the chapters also converge around key issues such as the disruptive effects of bringing new technological tools into established professional communities, the fine line between science popularization and science trivialization, and the feedback loops between science, mass media and public policy. The key theme that emerges is whether or not our increasing reliance on biotechnology in conservation enhances or undermines our relationship to what we define as wilderness. For proponents, the de-extinction narrative encompasses a progressive view of biotechnology as the solution to the biodiversity crisis, while, for opponents, it raises a false and dangerous hope that distracts from pressing problems of habitat destruction and climate change. Similarly, DNA barcoding and reproductive cloning are presented by advocates as essential to a lush and viable future, while critics tend to see only tools that will finally replace the real and tangible animal with a string of bio-digital code.

1.4 Telling Stories about Extinction

In order to analyze these issues, I focus on the language of extinction, on the stories, frames and metaphors we use to understand and to manage the complex interplay of politics, technology and culture involved in the biodiversity crisis. I want to understand how social actors use language—inclusive of rhetoric, metaphors, analogies and storylines—to mobilize key stakeholders, to attempt to build a broad public consensus around a course of action, and to focus sustained media attention on a specific public policy problem (Fletcher 2009). Discourse analysis is a powerful approach to analyzing wicked policy problems such as climate change and the extinction crisis "in which parties see issues, policies and policy situations in different and conflicting ways which embody different systems of belief and related prescriptions for action" (Schön and Rein 1994, p. xviii). Such intractable policy problems can be especially difficult to resolve via traditional public policy methods (such as cost-benefit analysis) because disputants begin from different worldviews and assumptions and thus interpret any new evidence or facts via competing and even contradictory lenses.

For example, in an analysis of the acid rain issue in Britain, M. Hajer (1993) asserts, "large groups of dead trees as such are not a social construct; the point is how

one makes sense of dead trees. In this respect there are many possible realities" (p. 44). Similarly, the disappearance of the baiji is *not* a social construct—it is a documented and material fact. Nevertheless, how stakeholders and the public understand this fact, how they make sense of competing claims about whom or what is to blame, and which interpretation gets translated into public policy and political action all merit analytical scrutiny. Discourse analysis directs our attention to how we make sense of large groups of disappearing species and also to the potential solutions—technological, political, and/or ecological— that we prioritize to deal with the problem. It requires close attention to multiple texts (mass media, speeches, legislation, documentaries, photographs, and policy documents) and can generate powerful insights about the relationship between language and public understanding of science, which in turn can inform effective public policies. As McBeth et al. (2007) argue, the goal of policy narratives is "to portray a political problem so that one's favoured course of action appears to be in the broadest public interest" (p. 88).

Attention to metaphor is another important tool of discourse analysis since "metaphors guide our expectations of the future" (Hellsten 2008). In a highly influential analysis of the use of metaphors in science communication by both opponents and proponents of genetic engineering, Dorothy Nelkin (2001) notes that "by connecting different orders of reality, metaphors enable the translation of very complex scientific information in culturally meaningful ways" (p. 556). Metaphors can be particularly important with respect to the public communication of environmental issues and the relationship between environmental problems and technology. For example, "with the advent of Spaceship Earth, nature itself became at once technological artefact and a vital object of Cold War gamesmanship" (Deese 2009, p. 70). Similarly, the Gaia metaphor, developed by James Lovelock in the 1970s, inspired a generation of activists with its insistence that the earth is a self-regulating complex organism that lives and breathes in a way analogous to human life.

1.5 Taking Control of Nature's Realm

In an influential analysis of molecular genetics in human health, Catherine Waldby (2002) argues that "genes were among the most privileged biotechnical actors of the twentieth century" (p. 305). I contend that the privileged status of genes now extends to environmental policy and wildlife conservation. As bioinformatics and genomics increasingly underwrite large-scale conservation projects, the various disciplines that comprise conservation science change, as does our relationship to nature and to animals. In one sense, the turn to biotechnology in wildlife conservation represents an incremental stage in a long chain of events that stretch back at least to René Descartes' influential notion of animals as machines in the seventeenth century, and arguably back to ancient Greece and Aristotle's theory of the *Scala Naturae*. Nevertheless, the accelerating rate of change and the potential disruptive effects of new biotechnologies on traditional conservation approaches and on the environment pose significant challenges and questions that need to be taken outside the lab and discussed widely in

society. New technologies such as DNA barcoding and somatic-cell nuclear cloning create tensions between established professional communities such as taxonomy and botany and the new gurus of the molecular age. Such large-scale and expensive research projects also reflect an era in which science is under increasing pressure to prove its worth to society and to provide tangible "returns" on public investment. Basic research in such areas as taxonomy, zoology and botany no longer commands sustained attention or significant funding in this post-Human Genome Project era, hence the race begins to molecularize these disciplines and bring them into sightline of Big Science. This book is thus also about very human stories of professional competition among scientists and universities, aggressive patent litigation, high-profile publicity stunts and quests for venture capital.

It is the idea of finally conquering extinction that definitively complicates efforts to keep genomic-based conservation within the boundaries of normal science and policy analysis. Elizabeth Pennisi (2002) notes that "too many false reports of recovered dinosaur DNA have sullied the field's reputation," which is arguably true, but the relationship between science fiction and fact becomes more complicated when our focus shifts from dinosaurs to species that went extinct in the more recent Palaeolithic period, such as the woolly mammoth or the sabre-tooth tiger, or to those that perished in the late 19th and early twentieth centuries. Many scientists in the new field of palaeogenomics—the study of the genomes of ancient organisms—are very uneasy about even discussing de-extinction, given the potential moral hazard inherent in thinking we have a reliable technological solution for extinction, as well as the extraordinary scientific developments that would be required in the future actually to accomplish such a project. However, the idea of creating life through technology, a trope that haunts the Western imagination, increasingly finds its way into legitimate scientific discourse (e.g., Lanza et al. 2000) and complicates attempts to keep palaeogenomics and associated fields within the boundaries of normal science. The woolly mammoth is the icon of this new era of de-extinction, generating headlines such as "Found, a perfect baby mammoth—they will be cloned in my lifetime says scientist after Siberia discovery" (Highfield 2007, p. 3), which then further smudge the blurry lines between tabloid and legitimate reporting, science fact and science fiction, and public communication and public manipulation in ways that bear closer scrutiny. In addition, as will be discussed, critics of such media accounts fear that this relentless focus on bringing back a woolly mammoth in the future distracts us from the species carnage taking place all around us right now.

Nik Rose (2001) reminds us that an "event is a matter of associations, of linking up a number of disparate little changes such that a threshold is crossed [and] that which was previously exceptional, remarkable, becomes routinely thinkable, perhaps even expected" (p. 16). Of course, what becomes routinely thinkable does not always become routine. History is littered with socio-technical imaginaries that didn't materialize, ranging from the Soviet Union's radiant future to travel via jetpacks. Nevertheless, the fact that we are now debating in the mass media, in science and in conservation politics the plausibility and desirability of bringing back extinct species indicates that we've crossed a crucial threshold in the human-animal relationship and in our expectations of technoscience. Just as Buckminster Fuller's

"Spaceship Earth" metaphor crucially shaped environmentalism in the 1960s, de-extinction is a powerful idea that implies (to the dismay of its critics) that we can now turn extinction—previously that most intractable and wicked of policy problems—into a solvable engineering problem, in much the same way as we figured out how to get a man to the moon and back again. As Adams et al. (2009) argue, anticipation is "the palpable sense that things could be (all) right if we leverage new spaces of opportunity" and reconfigure the possible through technological innovation (p. 246). If we begin to believe that we can reconfigure the immutable past into a vital past, intervene such that the past is no longer fixed but is malleable, then the future of nature becomes wide open and anticipatory. It even becomes possible, at the farthest edges of anticipation, to imagine a future nature teeming again with mammoths, mastodons and sabre-tooth tigers.

1.6 The Once and Future Baiji

In May 2007, a small group of people attended an exhibition on the Iowa River created to commemorate the last swim of the Yangtze River dolphin. The artist who documented the event noted that she "couldn't shake the image of the last baiji dolphin sinking to the bottom of the Yangtze without a goodbye, without a witness, silent" (Myers 2007). It is the silence of extinction that haunts the Western imagination and constitutes one of the most important metaphors in modern environmentalism. For example, Rachel Carson's extraordinarily influential *Silent Spring* (1962) focused mainstream attention on the cumulative effects of DDT use on wildlife, conjuring a nightmare future world in which wildlife has perished and the world has gone silent due to our chemicals and complacency. Stewart L. Udall (1963), former United States Secretary of the Interior (1961–1969), referred to "the quiet conservation crisis of the 1960s" in his efforts to raise the visibility of extinction on the public agenda. It is the uncanny calm of America's skies—emptied of the passenger pigeons that only years before had seemed "as inexhaustible as drops of water in the ocean or grains of sand on the shores" (McClung 1993, p. 33)—that haunts Allan W. Eckert's *The Silent Sky* (1965), a narrative account of the species' extirpation at the hand of man.

The 1960s emphasis on silence likely reflected growing fears of the potential annihilation that could be caused by the atomic bomb. Yet silence weaves through even earlier narratives, such as H. G. Wells's evocation of the end of the world in *The Time Machine* (1895):

> From the edge of the sea came a ripple and a whisper. Beyond these lifeless sounds the world was silent. Silent? It would be hard to convey the stillness of it. All the sounds of man, the bleating of sheep, the cries of birds, the hum of insects, the stir that makes the background of our lives, all that was over.

Silence is the final terrifying fact of extinction. Even modern science has begun to corroborate this instinctive fear and dread. Soundscape ecology, a relatively recent field in conservation, studies and attempts to catalogue all of nature's noise, a task

made all the more pressing and difficult as species rapidly disappear from the earth. Bernie Krause, one of the pioneer's of this new field, has in four decades gathered more than 4500 hours of sound from over 15,000 species. He tells us that, for example, "a coral reef that is alive has many different sounds, each fish species has their own signature, some gnaw on coral, others make noise with their swim bladders." Yet, in an uncanny echo of H. G. Wells, he notes as well that "a living reef is filled with all kinds of racket going on, whereas a reef under stress, dying or dead has almost no sound apart from the lapping of the waves above" (Irvine 2012). The silence of Krause's dead reefs becomes even more frightening when we find out that approximately 50 % of Krause's recorded archive—representing a lifetime of work in the field–comes from habitats that are now empty or extinct.

Ultimately, our technological interventions reveal much about what we fear and what we desire in an era in which intractable problems such as climate change and the biodiversity crisis exist alongside new technologies that seem to promise so much. As Stern (2006) argues, the "ultimate and inevitable loss experienced by the living is of course death. All bodies are destined to age and die, and this fact, in the context of a culture that presents the body as a major site for utopian fulfillment, generates feelings of anxiety and failure" (p. 78). The extinct animal, their images available now only through social media sites, fading zoo memorial exhibits or aging photographs and drawings, also generates its own feelings of anxiety and failure, not only because we failed them but because we may be inexorably failing ourselves. Susan Sontag, in a meditation on photography, once noted that in the nineteenth century, when we were afraid of wild animals, we used technology to shoot them. Later, as we became nostalgic for the ideal of untamed wilderness and all that we had lost or destroyed, we began to shoot them in a different way, with cameras, the photographer "now charging real beasts, beleaguered and too rare to kill" (Sontag 1971, p. 15). This book argues that in this new era of fear, when even nature photography, awash in a digital sea of images, is losing its power to compel our attention, we begin to barcode and clone.

Yet despite all of the salient ethical and scientific objections to the idea of de-extinction that will be discussed in this book, biotechnology seems in this historical moment to be where our hope for nature thrives, perhaps even hope for the baiji. According to a scientist at the Institute of Hydrology, Wuhan, China, Qi-Qi—the last known living baiji, who died in 2002—yielded to science a DNA library before she died. This means, we're told, that " 'the baiji genome could still be sequenced, and while reassembling an entire mammalian genome from scratch is not possible today, one day it will be' " (Carwardine 2007). The fundamental premise of this book is that whether or not the far side of bio-technoscientific conservation is reached in this century, the fact that we can now even conceive of actually bringing back the baiji one day indicates that this turn already poses significant questions for the natural world and for us. The degree to which society engages robustly with both the prosaic and the fantastical aspects of this era will shape the possibilities, desires, limits and ethics of our ambitions to restore lost worlds.

References

Adams V, Murphy M, Clarke AC (2009) Anticipation: technoscience, life, affect, temporality. Subjectivity 28:246–265

Braulick GT, Reeves RR, Ding W et al (2005) Report of the workshop on the conservation of the baiji and Yangtze finless porpoise. Institute of Hydrobiology, Wuhan, China, 28 November to 3 December 2005. http://www.iucn-csg.org/wp-content/uploads/2010/03/Brauliketal2005.pdf. Accessed 24 Mar 2013

Carwardine M (2007) The baiji: so long and thanks for all the fish. New Scientist 195(2621):50–53

China Daily (2006) Baiji functionally extinct—research. http://www.chinadaily.com.cn/china/2006–12/13/content_758268.htm. Accessed 23 Mar 2013

Coonan C (2006) After surviving twenty million years, China's goddess of the river is driven to extinction. http://www.independent.co.uk/environment/nature/after-surviving-20 million-years-chinas-goddess-of-the-river-is-driven-to-extinction-428933.html. Accessed 23 Mar 2013

Crutzen P, Schäwgerl C (2011) Living in the anthropocene: towards a new global ethos. environment 360 24 January. http://e360.yale.edu/feature/living_in_the_anthropocene_toward_a_new_global_ethos/2363/. Accessed 25 Mar 2013

Deese RS (2009) The artifact of nature: "spaceship Earth" and the dawn of global environmentalism. Endeavour 33(2):70–75

Eckert A (1965) The silent sky: the incredible extinction of the passenger pigeon. Little, Brown and Company, Boston

Fletcher AL (2009) Clearing the air: the contribution of frame analysis to understanding climate policy in the United States. Environ Politics 18(5):800–816

Frankham R, Ballou JD, Briscoe DA (2010) Introduction to conservation genetics. Cambridge University Press, Cambridge

Gerber L (2010) Conservation biology. Nat Educ Knowl 3(10):14. http://www.nature.com/scitable/knowledge/library/conservation-biology-16089256. Accessed 27 Mar 2014

Hajer MJ (1993) Discourse coalitions and the institutionalization of practice: the case of acid rain in Britain. In: Fischer F, Forester J (eds) The argumentative turn in policy analysis and planning. Duke University Press, Durham, p 43–76

Hellsten I (2002) The politics of metaphor: biotechnology and biodiversity in the media. Dissertation, University of Tampere

Hellsten I (2008) Popular metaphors of biosciences: bridges over time. Configurations 16(1):11–32

Highfield R (2007) Found, a perfect baby mammoth, they will be cloned in my lifetime says scientist after Siberia discovery. The Daily Telegraph, 11 July.http://www.telegraph.co.uk/science/science-news/3300165/Found-a-perfect-baby-mammoth.html. Accessed 25 Apr 2014

International Union for the Conservation of Nature—Cetacean Specialist Group (2006) Conservation of the Yangtze River Dolphin: emergency implementation meeting. San Diego, CA, 17–18 December 2005. http://www.iucn-csg.org/wp-content/uploads/2010/03/Turvey-et-al-2006-Conservation-of-the-Yangtze-River-dolphin-emergency-implementation-meeting-report.pdf. Accessed 23 Mar 2013

Irvine D (2012) Meet the man recording the sound of extinction. CNN.com, 21 September. http://edition.cnn.com/2012/09/20/world/eco-sound-ecology-bernie-krause. Accessed 25 Apr 2014

Lanza RP, Cibelli JB, Diaz F et al (2000) Cloning of an endangered species (*Bos gaurus)* using interspecies nuclear transfer. Cloning 2(2):79–90

Latour B (2004) Politics of nature: how to bring the sciences into democracy. Harvard University Press, Cambridge

Lyell C (1832/1991) Principles of geology, vol 2. University of Chicago Press, Chicago

MacLeod N (2005) Extinction. Encyclopedia of life sciences. John Wiley & Sons, Ltd., Chichester, p 75–80

McBeth MK, Shanahan EA, Arnell RJ, Hathaway PL (2007) The intersection of narrative policy analysis and policy change theory. Pol Stud J 35(1):87–108

McClung R (1993) Lost wild America: the story of our extinct and vanishing wildlife. The Linnet Books, Hamden
Myers JN (2007) The baiji's last swim. http://www.punkypip.com/index.php/tomorrow/the-baijis-last-swim-version-2/. Accessed 26 Apr 2014
Nelkin D (2001) Molecular metaphors: the gene in popular discourse. Nat Rev Genet 2:555–559
Pauly PJ (1987) Controlling life: Jacques Loeb and the engineering ideal in biology. Oxford University Press, New York
Pennisi E (2002) Ancient DNA untangles evolutionary paths. Science 295:2197
Rittel HWJ, Webber MM (1973) Dilemmas in a general theory of planning. Pol Sci 4:155–169
Rose N (2001) The politics of life itself. Theory, Culture & Society 18(6):1–30
Schön DA, Rein M (1994) Frame reflection: toward the resolution of intractable policy controversies. Basic Books, New York
Sontag S (1971) On photography. Penguin Group, New York
Soulé M E (1985) What is conservation biology? Bioscience 35(11):727–734
Stern M (2006) Dystopian anxieties versus utopian ideals. Sci as Culture 15(1):61–84
STS Research Platform (2012) Sociotechnical imaginaries. http://sts.hks.harvard.edu/research/platforms/imaginaries/. Accessed 25 Apr 2014
Turvey ST, Pittman RL, Taylor BL et al (2007) First human-caused extinction of a cetacean species. Biol Lett 3(5):537–540
Udall SL (1963) The quiet crisis. Holt, Rinehart and Winston, New York
Waldby C (2002) Stem cells, tissue cultures and the production of biovalue. Health 6(3):305–323
Walsh B (2009) The new age of extinction. Time, 2 April. http://content.time.com/time/specials/packages/article/0,28804,1888728_1888736_1888858,00.html. Accessed 28 Mar 2014
Wells HG (1895/2011) The time machine: an invention. Martino Fine Publishing, Connecticut
Western D (2001) Human-modified ecosystems and future evolution. PNAS 98(10):5458–5465

Chapter 2
A Political History of Extinction

Abstract In the 1870s, an estimated 60 million bison (also known as buffalo in the United States) roamed the Western plains of North America, though by the early twentieth century only 541 documented animals remained. In 1905, President Theodore Roosevelt, himself an avid hunter, called the extirpation of the buffalo a tragedy for the natural world, and the era of organized environmentalism and preservation began. Today, in yet another significant turn in environmental science and politics, bison are subject to the high-tech interventions of the biotechnological age. The story of the bison illustrates every important stage in the development of American environmental politics: deliberate efforts to weed out the abundant species in the 1800s, followed by its allegorization in the mid-twentieth century and then efforts to restore the original herds through high-tech reproduction today. This chapter begins with that story as a precursor to analyzing the cultural path of the idea of extinction as it moved from the rarefied worlds of philosophy and science to the chaotic and messy domain of politics. It begins with a brief discussion of extinction debates in the Enlightenment era then analyzes the development of nature conservation from the Progressive Era to today. The chapter concludes with an introduction to the new politics of hope that is embedded in the idea of de-extinction through the use of advanced biotechnologies.

> *Species and groups of species gradually disappear one after another, first from one spot, then from another, and finally from the world.*
>
> – Charles Darwin (1859)

2.1 From Eden to Extinction. . . and Back Again?

It must have been magnificent, the American wilderness prior to the arrival of human beings. Charles Darwin had observed in the 1840s that "it is impossible to reflect on the changed state of the American continent without the deepest astonishment. Formerly it must have swarmed with great monsters; now we find mere pigmies, compared with the antecedent, allied races" (Glasgow Herald 1845). Indeed, the North American continent during the Pleistocene teemed with majestic megafauna, including the giant sloth, American lion, giant condor, Columbian mammoth and dire wolf. The Clovis people, the ancestors of most Native Americans, arrived on

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the continent during the Pleistocene, approximately 12,600 years ago (Raff and Bolnick 2014). Today, scientific debate continues over whether these first arrivals were primarily responsible for killing off the megafauna or if the blame should be placed on climactic change, disease outbreaks, or impact from an asteroid (or some combination of the four factors). In 1492, Christopher Columbus was the first European to discover America. For the early European settlers who followed, the continent seemed to stretch out forever and to contain an inexhaustible supply of food, resources and formidable natural vistas. As Leo Marx (2012) argues, from "Jamestown in 1607 to the closing of the Western frontier in 1890, the encounter of white settlers with what they perceived as wilderness—unaltered nature—was *the* defining American experience" (p. 8).

The sheer number of animals alive on the continent in Darwin's day is itself astonishing to us now. In his time, the skies and glades of the United States would have been lush with passenger pigeons and Carolina parakeets and the forests with megafauna such as the California Golden Bear, Merriam's Elk, and the Banks Island Wolf (all extinct by the 1920s). Well into the nineteenth century, over 60 million bison roamed the Western plains, making them the single biggest herd of land animals in the world. John Filson had written in 1784 of " 'the amazing herds which. . . fill the traveller with amazement and terror' " (Portman 2011).

Native American tribes traded bison skins for knives, firearms and tobacco. By 1850, however, killing bison (Fig. 2.1) became a key tool by which white settlers sought to conquer the Native American populations and to starve the plains Indians into surrender by eliminating his principle source of food (Congressional Quarterly 1967). Construction of the Union Pacific Railroad in the 1860s accelerated the virtual extirpation of the bison. Between 1870−1875, at least 2.5 million bison were killed per year, in order to clear spaces for the railroads, domesticated cattle herds and new settlements. By 1883, approximately 10,000 bison remained, these numbers eventually reduced to a remnant herd of 541 though the ongoing predation of both Cree Indians and white hunters in North Dakota.

The bison story exemplifies the contrast between the Edenic landscape of the pre-European American continent and the effects of the rapid industrialization that accelerated in the mid nineteenth century. As Joshua Johns (1996) argues, "two primary views of the wilderness were contested: the wilderness either contained savagery and temptation which threatened the authority of the community or it represented a new Garden which could flourish with the proper cultivation by the European settlers." A century before the highly visible environmental movements of the mid-twentieth century emerged, the tension between preservation and progress had already become a defining trait of the American worldview. In 1905, for example, President Theodore Roosevelt and conservationist William Hornaday responded to the seemingly imminent extinction of the bison by creating the American Bison Society to push for restoration of the species. Only thirty years earlier, a newspaper article, reflecting the influence of Social Darwinism on the culture at that time, had predicted that, "railways and hunters are crossing and recrossing every trail of these animals, and they're being crowded out with the same certainty as are the redskins. Neither buffalos or Indians are creatures of civilization; and the struggle against them seems

Fig. 2.1 Bison grazing, circa 1900. Library of Congress, LC-USZ62-20138, http://catalog2.loc.gov/

to be irrepressible" (Daily Evening Bulletin 1873). Yet by the turn of the twentieth century, the American President, himself an avid hunter, had concluded that "the extermination of the buffalo has been a veritable tragedy of the animal world" (National Park Service n.d.) and the era of organized environmentalism had begun.

Today, in another significant turn in environmental science and politics, bison are subject to the high-tech interventions of the biotechnological age. In 2012, for example, a purebred baby bison born at the Bronx Zoo was the much-anticipated consequence of transferring the genetic material of a Yellowstone bison (one of two remaining herds in Yellowstone National Park which can be traced to the original American bison) to a surrogate commercial bison (Moscowitz 2012). Tod Hansen, director of the Animal Reproduction and Biotechnology Laboratory at Colorado State University, stated that " 'this is a great achievement to add to our list of accomplishments....We can use these genetics so they can go into other herds. The project will serve as a model for mitigating diseases... in genetically valuable bison' " (Phys.org 2012). Such purebred bison will likely be transferred to the American Prairie Reserve, a restoration project that seeks to cultivate and preserve an authentic prairie landscape on a 3 million acre site in Montana.

The story of the bison illustrates every important stage in the development of American environmental politics: deliberate efforts to weed out the abundant species in the 1800s, followed by its allegorization in the mid-twentieth century and now efforts to restore the original herds through high-tech reproduction today. This chapter begins with that story as a prelude to analyzing the idea of extinction as it travelled

from the rarefied worlds of philosophy and science to the chaotic and messy domain of politics. The next section continues with a discussion of the debate about extinction in the Enlightenment era then proceeds in the third section to review major political events in the development of nature conservation and environmentalism in the twentieth century. The fourth section focuses on the discourse of environmental catastrophe that begins to take hold by the 1980s, exemplified by the urgency surrounding pleas for global intervention to mitigate climate change and halt the biodiversity crisis. The chapter concludes with an introduction to the new politics of environmental hope embedded in the idea of de-extinction.

2.2 Fossils and Frontiers: Debating Extinction During the Enlightenment

The founding of the United States intersected with the height of the Scottish Enlightenment. For example, it is apt that the Declaration of Independence and Adam Smith's *The Wealth of Nations* were both released to the world in 1776. The early founders of the United States were generally men of science and reason and many of them engaged directly with the learned debates swirling in their day around questions of extinction, evolution, and geological time. Thomas Jefferson (1743–1826), in particular, was fascinated with collecting the bones of the American mastodon (Fig. 2.2) and believed that the Lewis and Clarke expedition (1804–1806) would uncover evidence of living mastodons in the western United States (Thomson 2011). Jefferson seriously doubted that extinction occurred, arguing in 1787 that "such is the economy of nature that no instance can be produced of her having permitted any one race of her animals to become extinct; of her having formed any link in her great work, so weak as to be broken" (Monticello.org n.d.). Jefferson turned out to be wrong, of course, but in his era the idea of extinction remained extraordinarily controversial within science and philosophy. Western science had been heavily influenced by Aristotle's classical notion of the Scala Naturae, along which the natural world and its species could be arranged on a single continuum, progressing from the lowest orders to the highest. By the medieval period, the Scala Naturae had morphed into the influential idea of the Great Chain of Being. This belief held that everything in the universe was placed in a divinely sanctioned hierarchical order, determined by its relative mixture of spirit and matter. Things that were mostly matter, such as rocks and minerals, occupied the lowest rungs of the ladder and were succeeded by plants, animals, humans and angels. At the very top of the ladder was God (Melani 2009). The strong philosophical and religious commitment to the idea of the Great Chain of Being made extinction unimaginable for most people at this time, even those committed to science (Barrow 2011, p. 429).

It was only in 1796 that Georges Cuvier (1769–1832) firmly established the fact of the extinction of species (Ladle and Jepson 2010, p. 98). Cuvier had already been profoundly influential in developing the fields of comparative anatomy and palaeontology and among his most famous fossil findings were those of the American

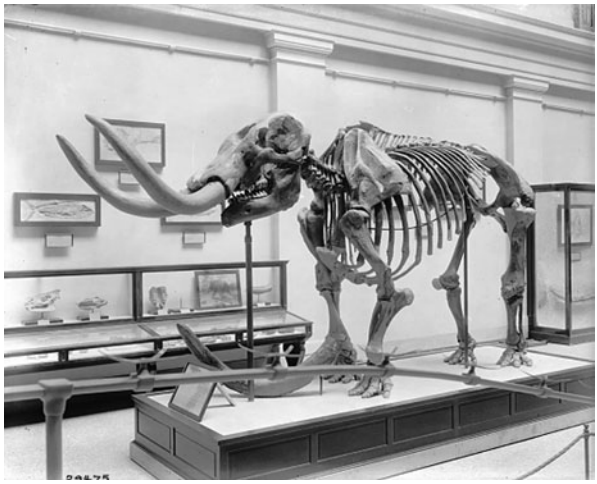

Fig. 2.2 American Mastadon, Palaeontology Hall, Natural History Museum, circa 1917. Library of Congress, 29475 or NHB-29475, http://catalog2.loc.gov/

mastodon (*Mammut americanum)* and the Megatherium (a giant prehistoric sloth whose remains were excavated in Paraguay). He also expanded Linnaean taxonomy by grouping classes into the higher classification of phyla and was among the first to conjecture that reptiles, rather than mammals, had dominated the Earth in the prehistoric era. In 1796, reading a research paper at the Ecole Centrale du Pantheon, Cuvier presented work on fossils that established that African and Indian elephants were different species and also that the mammoth (*Mammuthus primogenus)* must be extinct.

Yet not even Cuvier could see in his time what Charles Darwin would see in his, only 50 years later. Cuvier explicitly rejected the idea of evolution, proposing instead, in his 1813 Essay on the Theory of the Earth, a catastrophist thesis which theorized that new species were created periodically after great floods. By Cuvier's reasoning, species were created de novo after each major catastrophic event; they did not progressively evolve over time. Cuvier's work is nonetheless instrumental to this story since, "by the 1830s, when Charles Darwin entered the scene, the factuality of extinction was not in question. What remained open was the correlation of the extinction of species with geological change" (Herbert 2005, p. 58). That species adapt, compete and disappear over spans of geological time is one of the most crucial and profoundly influential insights of Charles Darwin's *On the Origin of Species* (1859). Despite ongoing debates within contemporary science about the exact mechanics of the process, the theory of adaptation by natural selection now constitutes central dogma in biology and molecular genetics (Cartwright 2000). The philosopher Daniel Dennett has likened Darwin's idea, which is so absolutely essential to contemporary Western society and science, to a "universal acid; it eats through just about every traditional concept and leaves in its wake a revolutionized world-view" (Dennett 1996, p. 63).

Following Darwin, Walter Rothschild developed the first systematic account of extinction, elaborated in his lecture "On Extinct and Vanishing Birds," delivered

at the 4th Ornithological Congress in 1905 (Ladle and Jepson 2010). Five years earlier, Hugo de Vries, Carl Correns and Erich von Taschermak had established the foundation for the field of molecular biology via their rediscovery of Gregor Mendel's great work on inheritance patterns in plants. The subsequent synthesis of Mendel's findings with Darwin's theory of natural selection, bolstered by further breakthroughs such as T.H. Morgan's theory of the chromosome and the work of R. Fisher, J.B.S. Haldane and S. Wright on population genetics, inaugurated the modern age of genetics. By the Progressive era, despite the dangerous detour of the eugenics period (Bashford and Levine 2010), the scientific foundations of extinction were firm enough that the issue could be recast as a political problem, subject not only to inexorable natural laws but to the interventions and choices made by societies.

2.3 The Politics of Extinction in the Progressive Era

In the late nineteenth century, the question of extinction begins to shift from the elite realms of philosophical and scientific debate to the chaotic domain of politics. In 1872, the United States created the world's first national park, Yellowstone Park, covering parts of the states of Wyoming, Montana and Idaho. By 1890, Sequoia National Park and Yosemite National Park had both been established in California. The Lacey Act (1900) was the first to protect wildlife and regulate its killing and sale and was followed quickly by the formation of the National Association of Audubon Societies for the Protection of Birds and Animals in 1901. This rapid proliferation of environmental legislation, civic associations and national parks reflected the particular intellectual influence of John Muir and Gifford Pinchot. Both men were highly respected scientists. While each cherished the American wilderness, Muir and Pinchot, respectively, came to symbolize the tension between unaltered nature and sustainable use in ways that persist today. John Muir placed intrinsic value on nature, arguing that "everybody needs beauty as well as bread, places to play in and pray in where nature may heal and cheer and give strength to body and soul alike" (Muir 1912). He was no dreamy idealist, however. In that same article, written in response to the controversial proposal to dam the Hetch Hetchey Valley, Muir excoriated "these temple destroyers, devotees of ravaging commercialism, [who] seem to have a perfect contempt for Nature, and, instead of lifting their eyes to the God of the mountains, lift them to the Almighty Dollar." Gifford Pinchot, in contrast, is often referred to as the "father of sustainable use." He believed that a balance had to be struck between economic growth and conservation, but he stressed that wise use of America's natural resources provided the key to both national security and extraordinary prosperity. For Pinchot, "the object of our forest policy is not to preserve the forests because they are beautiful... but [for] the making of prosperous homes. ... The first great fact about conservation is that it stands for development" (Pinchot 1910).

Muir and Pinchot's worldviews remain essential touchstones in American environmental politics. Despite the ongoing friction between the two worldviews, once

extinction becomes understood both as a process that adheres to discoverable natural laws *and* as a problem that can be exacerbated by human beings via unrestrained development, the way is paved for the emergence of today's existential preoccupation with both climate change and the biodiversity crisis. Robin and Carruthers (2011, p. 3) remind us that Charles Darwin "put history into biology with his daring idea that nature was not immutable, it was—in fact—history, exhibiting change over time." What is significant about the early twentieth century is the way in which human beings begin to write themselves into the history of nature, begin to recognize and respond to the ways in which modern societies damage and distort the natural laws elucidated by Charles Darwin and Alfred Russell Wallace. The corollary to Robin and Carruthers's insight is that Darwin, having put history into biology, also forces us to consider not only the past and the question of how we got here but the future and whether and how nature (and human beings) can survive.

Wilderness and the damage man was doing to it was the shadow side of the general social and political optimism of the Progressive era. By the 1920s, observers had begun not only to notice the decimation of species (particularly large mammals) but to connect the destruction to something perhaps inherent in the Western mindset. For example, when Viscount Allenby spoke before the British House of Lords in 1929 about the disappearance of African fauna, he argued that "civilised man goes out and upsets the whole balance of nature with his rifle. . . . The modern tourist-hunter in a hurry will shoot sometimes just for fun (United Kingdom House of Lords 1929, p. 633). Earlier, in the Royal African Society's learned journal, E. Buxton referred to African wildlife as an Imperial asset and raised the question of how future generations would judge those allowing the slaughter to continue (Buxton 1921, p. 279). In the *Journal of Mammalogy*, H. Carey begins with a roll call of already extinct and endangered American species such as the pronghorn antelope, prairie hen, heath hen and passenger pigeon, before shifting to an impassioned plea for nations to recognize a collective international interest in saving African wildlife. Drawing upon the then-salient influence of both the League of Nations and the Russian Revolution of 1917, Carey ends with a call for a wildlife preservation campaign that is "militant, unified [and] international" (Carey 1926, p. 78).

The statements above reflect the culture of their time in ways that may sound jarring to us today. Nevertheless, they are a crucial pivot from the belief that the elimination of "exotic" species in the colonies was an inevitable consequence (and prerogative) of Empire to a nascent awareness that nature and wildlife would vanish forever without political interventions on a national and international scale. Despite the lingering cultural biases in their work, the new environmental worldview signalled by observers such as Buxton and Carey represents a radical re-framing of the extinction problem, one that bridges the nineteenth and twenty-first centuries. The same rough pattern of events and intellectual developments repeated throughout Australia, New Zealand and Western Europe in this timeframe. As a key example, to be discussed at length in chapter five, an essay on the disappearance of Australia's thylacine equated the zoological history of the nineteenth century with the word "extermination" and compared the slaughter of the natural world to Omar's destruction of the Alexandrian library in the Classical Age (Renshaw 1905, p. 216).

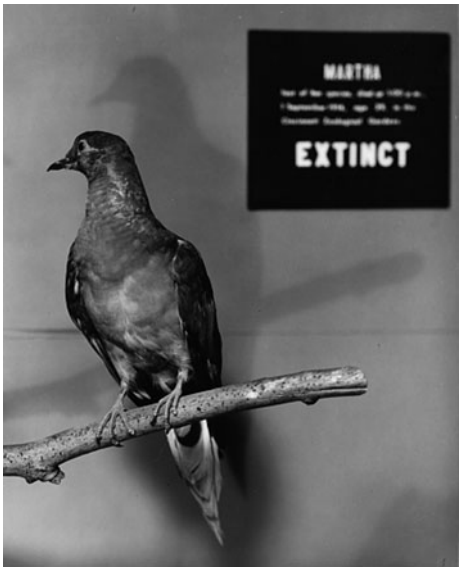

Fig. 2.3 Martha, a Passenger Pigeon. Smithsonian Institution Archives, SIA2010-0612 and MNH-917, http://www.si.edu/

In the United States, the passenger pigeon became the paradigmatic twentieth century symbol of man's new responsibility towards wildlife, both because of the immensity of its initial numbers and the rapidity with which shooting it for food and sport decimated the species. Like the bison, passenger pigeons originally flourished in such numbers as to seem inexhaustible. James Audubon estimated in 1813 that, in one season, one billion birds must have flown over the Ohio River in Louisville, Kentucky. Within a century of Audubon's observations, the multitudes had been reduced to a lone passenger pigeon named Martha, who died in 1914 at the Cincinnati Zoological Gardens before being shipped in ice to reside in perpetuity at the Smithsonian Institution in Washington, DC (Fig. 2.3). The last confirmed sighting of a passenger pigeon in the wild had occurred in 1900. While researching this book, I came across an old copy of Allan W. Eckert's *The Silent Sky: the Incredible Extinction of the Passenger Pigeon* (1965) at the Lawson-McGhee Public Library in Knoxville, TN. The book was shelved in non-fiction, as per its classification, and does include the historically documented events in the extirpation of the passenger pigeon. Yet the book is written in the style of a novel. In the fifty years between the death of Martha and the publication of this book, the story of the passenger pigeon's demise became an American allegory, rendered deftly and evocatively by Eckert. The last sentence of the book closes with a scene of irremediable sadness, as a young boy who has received a BB-gun for Christmas goes out to shoot birds in his backyard and carelessly kills the last wild passenger pigeon. Eckert speculates if "in that fractional instant before he died, the old passenger pigeon may have heard the gust of wind which swept through the tops of the trees with a sound not unlike the murmur of a million distant wings" (Eckert 1965, p. 239).

2.4 Spaceship Earth: Twentieth Century Environmentalism

In 1965, the same year that Eckert eulogized the passenger pigeon, the United States Congress held hearings on The Wilderness Act. One expert witness recalled Aldo Leopold's observation in the *Sand County Almanac* that, "for one species to mourn the death of another is a new thing under the sun. We, who have lost our pigeons, mourn the loss. Had the funeral been ours, the pigeons would hardly have mourned us. In this fact, rather than in nylons or atomic bombs, lies evidence of our superiority over the beasts" (Leopold 1949). The cataclysmic events of the Great Depression and World War II had temporarily reduced the salience of wilderness preservation in the 1930s and 1940s, though President Franklin Roosevelt's New Deal did provide important opportunities and resources to pursue large-scale restoration projects. The Tennessee Valley Authority (TVA), for example, worked with farmers to improve cultivation techniques, replant forests and improve wildlife habitat. The Civilian Conservation Corps (CCC), which began operation only 37 days after Roosevelt took office, was another very successful New Deal program. Often referred to as "tree troopers" or "soil soldiers," the approximately 3.5 million men employed by the CCC built an estimated 13,100 miles of foot trails, planted between 2 billion and 3 billion trees, restocked 972 million fish in America's streams and ponds, and developed 800 state parks. The CCC ended in June 1942, as America shifted towards war-time industrial production following the Japanese attack on Pearl Harbor and the economy reached almost full employment. The need for men to join the War effort as soldiers took precedence in this timeframe (Fletcher (2010).

The conservationist momentum of the Progressive era accelerated again after World War II. By the early 1960s, books such as Rachel Carson's *Silent Spring* (1962) presaged an increasingly public dimension to what had been largely scientific and policy-oriented discussions within relatively elite circles. The book appealed to a general audience and alerted the public to the potential dangers of DDT (dichlorodiphenyltrichloroethane), an insecticide then being promoted for use for farm crops. President John F. Kennedy responded to the furor around the book by having his Science Advisory Committee review Carson's major findings. Public and media attention to environmental issues also began to extend from the chemical industry to the nuclear power industry, species extinction, water pollution and urban blight.

One of the most iconic symbols of the nascent environmental movement was the image "Earthrise," a photograph taken of the earth over the lunar horizon by the manned Apollo 8 space mission in December 1968. A quote attributed to the British astronomer, Sir Fred Hoyle (1915–2001), asserted in 1948 that "once a photograph of the Earth, taken from the outside, is available, a new idea as powerful as any in history will be let loose" (Brand 1982, p. 430). Twenty years later, this first image of the Earth, small and beautiful, floating within an infinite universe, did seem to encourage a shift in perspective from hubris to humility. In the documentary *The Shadow of the Moon* (2007), Mike Collins, an Apollo 11 astronaut who is among the few to have actually seen Earth from a distance in orbit, reflected that "oddly enough

the overriding sensation I got looking at the earth was, my god that little thing is so fragile out there." The metaphor of Spaceship Earth, which David Deutsch (2011) criticizes today as highly inaccurate in a technical sense, reverberated emotionally and politically throughout the 1960s and 1970s by directing our attention to the Earth as both fragile and finite. Indeed, the metaphor even reached the upper echelons of the United Nations, when the then-Secretary General U Thant commemorated Earth Day 1971 with the words, "May there only be peaceful and cheerful Earth Days to come for our beautiful Spaceship Earth as it continues to spin and circle in frigid space with its warm and fragile cargo of animate life" (West 2014).

2.5 Climate, Catastrophe and Conservation Biology

The optimism engendered by the image of Earthrise in 1968 co-existed uneasily with a sense of imminent catastrophe that also begins to permeate the environmental movement by the late 1960s. In 1967, the American cultural critic and conservationist John Wood Krutch wrote, "a case could certainly be made out for the contention that modern man as a race has a death wish. Otherwise, he would not be marching so resolutely toward literal extinction" (McClung 1993, p. 252). The year 1968 represented the apex of the Cold War nuclear arms race between the United States and the Soviet Union, prompting the signing that year of the Treaty on the Non-Proliferation of Nuclear Weapons (effective 1970). The idea of the potential mutual assured destruction (M.A.D.) of the planet due to Cold War political machinations animated the international environmental movement. Moreover, mass market books such as *The Population Bomb* (Erlich and Erlich 1968), which predicted mass starvation in the 1980s due to over-exploitation of the natural environment, and *Future Shock* (Toffler 1970), which focused on the dislocation caused by rapid social and technological change, amplified the sense that both the environment and man's place in it was spinning wildly out of control.

The mainstreaming of the environmental movement by the 1970s was the most visible success of 1960s activism. For example, President Richard Nixon signed significant federal legislation such as the *Clean Air Act* (1970), the *Water Pollution Control Act* (1972) and the *Endangered Species Act* (1973). At the same time, fueled by the new rhetoric of pending catastrophe, segments of the movement begin to take on a much more militant character, as seen through the formation of groups such as Earth First in 1979. In addition, as Benjamin Bühler notes, as "the whole discussion in the 1970s takes it as a given, that the limitations of economical growth is the most important issue" (Bühler 2011). The uneasy but workable co-existence between the worldviews of Muir and Pinchot that defined the Progressive Era thus begins to fragment by the early 1980s into a starkly rendered and mass media exacerbated partisan war between environmentalists on the side of nature and corporations on the side of profit. President Ronald Reagan's New Federalism was partly a response to the sluggish economy of the late 1970s and a bloated federal bureaucracy. Nevertheless, both economic and political retrenchment from environmental preservation

during the 1980s—embodied in funding cuts and in the Administration's belief in only a minimal role for federal intervention in state-level conservation or wildlife protection—magnified the sense among activists and many scientists that the bipartisan environmental politics of the 1950s and 1960s had, by this point, devolved into a series of zero-sum conflicts.

By the late 1980s, "the idea that a nuclear winter could alter the climate of the whole planet and lead to the extinction of life was the first of a series of putative/environmental catastrophes of global proportion, derived from increasingly sophisticated computer-generated models" (Cosgrove 2008, p. 1873, 1874). Though the issues of climate change and global warming would not reach their political apogee until the early twenty-first century, concerns about potentially catastrophic climactic disturbances brought about by excessive carbon emissions found a cultural corollary in a renewed pop fascination with the fate of the dinosaurs, finally wiped out in a mass extinction event that had ended the Cretaceous Period. For example, in his book *Life Pulse: Episodes from the Story of the Fossil Record,* Niles Eldredge, a scientist at the American Museum of Natural History, exults that when the T-Rex appeared on the cover of Time magazine in 1984, "we knew that extinction had hit the big time" (Eldredge 1987, p. 201). Michael Crichton's extremely popular novel *Jurassic Park* appeared in 1990. While discussed more fully in chapter five, it is important to note that the best-selling novel introduced a mainstream audience to the idea, however speculative, that recent in advances in genetic engineering would one day allow scientists to bring back extinct species that had perished. The cultural power of the Jurassic Park metaphor only increased upon the release of Steven Spielberg's blockbuster film version in 1993. Increasingly, parallels were drawn in the mass media and political discourse between the elimination of the dinosaurs in deep time and the scale of the extinction crisis facing us in the present. A paper from the Worldwatch Institute in the late 1980s, for example, warned readers that "more species of Earth's flora and fauna may disappear in our lifetime than were lost in the mass extinction that included the disappearance of the dinosaurs 65 million years ago" (Wolf 1987, p. 6).

From a conservation science perspective, the crucial activity in this era is the attempt to move funders, the public and the mass media from focusing primarily on the last-ditch conservation of charismatic species such as lions and pandas to valuing biodiversity in a holistic sense. The United Nations Environmental Program (UNEP) defines biodiversity, which occurs at the levels of genes, species and ecosystems, as "the number, variety and variability of living organisms... a synonym of 'Life on Earth" (UNEP 2014). The concept of biodiversity gained media salience in the 1980s both because of the intrinsic value of species variability but also within a new framework that stressed how the ecosystem provided valuable "services" to society. Echoes of Gifford Pinchot could be heard in this new discourse, which focused on environmental goods including food, pollination and medicines. Erik Eckholm encapsulates the new/old view in the *New York Times*, emphasizing that "knowledge of species diversity is the foundation of ecological understanding... and also provides the essential raw materials for new genetic engineering technologies" (Eckholm 1986, p. C1). The renowned entomologist E.O. Wilson was particularly

influential in promoting the concept of biodiversity. He urged governments to fund and participate in a global species inventory, putting the effort to catalog the Earth's biodiversity into the "same category as doing a complete map of the human genome" (Eckholm 1986, p. C5). By the early 1990s, the end of the Cold War opened up a space for the consideration of global issues that lay outside the traditional high-politics domain of nation security. For example, at the G-7 Summit of 1989, "for the first time, environmental issues will take center stage.... None of today's gravest environmental challenges can be met without a new era of cooperation between the industrial countries represented at Paris and the developing countries of the Third World" (Speth 1989, B5). The 1992 Earth Summit held in Rio de Janeiro produced both the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change.

Study of the linkages between biodiversity, genetics and society found a professional home in the discipline of conservation biology, which seeks to "evaluate human impacts on biological diversity and to develop practical approaches to prevent the extinction of species" (Gerber 2010). The young field emerged out of the environmental crises and political ferment of the 1960s, with Sir Otto Frankel credited with initially emphasizing the importance of genetic factors, such as the mitigation of inbreeding depression, in effective wildlife management (Frankham et al. 2010). Michael Soulé (1985), one of the key scholars of conservation biology, described it as a "mission-oriented crisis discipline" that is explicitly interdisciplinary, drawing from numerous scientific fields such as biology, geology, epidemiology, restoration ecology, chemistry and genetics, as well as social sciences such as public policy, law and anthropology. Conservation biology's emphasis on on a distinct mission—saving biodiversity—requires a level of political visibility and public outreach often higher that found in more classical disciplines such as physics or chemistry. It also corresponds to Harold Lasswell's (1970) famous call for real-world, problem-focused policy studies and for professional policy analysts to learn to mediate between knowledge and action.

Contemporary conservation genetics—a key component of conservation biology—is the study of "genetic management of small populations, resolution of taxonomic uncertainties and management units, and the use of molecular genetic analyses in forensics and to understanding species' biology" (Frankham 2003). Since the 1980s, the conservation genetics tool-kit has expanded to include frozen zoos, assisted reproduction and, more controversially, experimental cloning of endangered species (see, for example, Lanza et al. 2000). Molecular biology now provides not only crucial information for conservation but, in conjunction with information technologies, a potential new approach to conservation and wildlife restoration. Of course, human manipulation of germplasm in livestock and plants is a practice at least 10,000 years old; indeed, artificial selection served as a useful analogy in Darwin's attempts to explain his new theories of natural selection (Cornell 1984). However, our ability today to find, extract, manipulate and even reconstruct strands of DNA means that the biotechnological turn in conservation now dominates media representations of and political interest in wildlife management in the early twenty-first

century. Mitchell (2003, p. 483) uses the term "biocybernetic" to refer to "the combination of computer technology and biological science that makes cloning and genetic engineering possible." A major theme to be explored in the remainder of this book is the implication of "biocybernetic conservation," an approach that constitutes not only a new and powerful set of tools but also a worldview that renders wildlife and nature as sites of information code that can be decoded, debugged and even rewritten. If, as *National Geographic* contends, de-extinction is "no longer a fantasy" (2013), it is because the technoscientific and political histories of conservation since the nineteenth century have brought us full circle to a point at which pending environmental catastrophe (on an even larger scale than we could have conceptualized in the 1800s) co-exists alongside a renewed optimism that technological progress provides the surest path back to Eden.

2.6 Everything Old is New Again: Biotechnology and De-Extinction

Raymond Williams (1983, p. 219) once argued that "nature is perhaps the most complex word in the language." For Robert Gottlieb (2007, p. 20), if this is true, "that's partly due to how its meanings and reference points are continually changing" (Gottlieb 2007, p. 20). Certainly, the path from colonialism to the Progressive era to Spaceship Earth and to de-extinction and rewilding would seem in many ways to bear out Gottlieb's observation. Yet in the most fundamental way, we remain poised at the dawn of the twenty-first century on the same dilemmas that beset us in the nineteenth century. In 2009, *Time* magazine published a special issue on the environment entitled "Vanishing Act: How Climate Change is causing a New Age of Extinction," in which the ghosts of Pinchot and Muir once again attempt to square the circle between the social and the spiritual value of nature: "the same natural qualities that sustain wildlife—clean water, untainted land, unbroken forests—ultimately sustains us as well, whether we live in a green jungle or a concrete one. But there is an innate value to untrammeled biodiversity too—one that goes beyond our own survival. When that is lost, we are irretrievably diminished" (Time 2009, p. 31).

As the 21 century begins, we straddle environmental peril and possibility. The global biodiversity crisis is the most significant existential issue facing humanity. The 2007 Red List of the International Union for the Conservation of Nature, for instance, identifies 16,306 species (out of 41,415) as threatened with extinction (IUCN 2007). Though scientists may disagree on whether or not the background extinction rate is 1,000 or even 10,000 times higher than it should be under normal, non-anthropogenic circumstances, "even conservative estimates predict that global species loss could reach as high as 30 percent of total species by the early decades of the next century, by the time today's children have children (Novacek 2001, p. 12)." The extinction crisis today is not the fault of nature but of politics, of such factors as the inexorable expansion of human settlements into wilderness habitats, ongoing military conflicts in areas of ecosystem and species vulnerability, and the persistence

of illegal trade in endangered species. The problems are intractable, even wicked; as Bawa et al. (2004, p. 859) remind us, "in spite of decades of conservation efforts, biological diversity throughout the world continues to dwindle."

Yet dwindling species leave traces (as Cuvier and Darwin knew) in the form of fossils, and also, as we now know, in genes. The myriad bottled specimens and preserved skins archived in natural history museums and university collections throughout the world constitute for many environmentalists the tangible evidence of colonial crimes against nature. Paradoxically, these same imperialist relics may now contain the means to restore at least some of our most lamented lost species. This new discourse of de-extinction, which finds its inspiration in recent advances in molecular biology, finds a parallel in the recent development of the rewilding agenda. Michael Soulé, once so influential in the development of the field of conservation biology, introduced the idea of rewilding in the 1990s. Essentially, rewilding—a term now used often in environmental debates in the United States, Canada and Europe—seeks to not only to restore landscapes but to recreate empty swathes (or corridors) of continent in which large megafauna can again roam. Like the idea of de-extinction, rewilding reframes the rhetoric of environmental catastrophe into one of hope. Seeking to retrieve the Edenic past as a way into a sustainable ecological future, the rewilding imaginary brings us back to the bison. Appropriately, one of the earliest rewilding projects seeks to reintroduce a small herd of genetically pure wood bison—relatives of the plains bison that once proliferated throughout North America—into Pleistocene Park, an Ice Age nature reserve under construction in Siberia. The goal of Pleistocene Park, as Nikita Zimov notes, "is to regenerate the ecological system with the help of animals that lived here thousands of years ago" (Page 2006). Should biotechnology eventually make it possible, Pleistocene Park would also welcome the reintroduction of the woolly mammoth.

References

Barrow MV (2011) The specter of extinction: taking a long view of species loss. Environ Hist 16:428–432

Bashford A, Levine P (eds) (2010) The Oxford handbook of the history of eugenics. Oxford University Press, New York

Bawa KS, Seidler R, Raven HP (2004) Reconciling conservation paradigms. Conserv Biol 18(4):859–860

Brand S (1982) Earth flyby. New Sci 94(1305): 430

Bühler B (2011) Out of control: fictions of the future in the discourse of political ecology. Paper presented at the AHRC Research Network meeting on the cultural framing of environmental discourse, University of Bath, 27 February—1 March 2011

Buxton E (1921) The preservation of species in Africa. Afr Aff XX (LXXX):279–283

Carey H (1926) Saving the animal life of Africa: a new method and a last chance. J Mammol 7(2):73–85

Cartwright J (2000) Evolution and human behavior. The M.I.T. Press, Cambridge

Congressional Quarterly (1967) Wildlife preservation. The CQ Researcher, 10 May

Cornell JF (1984) Analogy and technology in Darwin's vision of nature. J Hist Biol 17(3):303–344

Cosgrove D (2008) Images and imagination in 20th century environmentalism: from the Sierras to the Poles. Environ Plan 40(8):1862–1880
Daily Evening Bulletin (1873) Extinction of the buffalo. The Daily Evening Bulletin, 5 August (102)
Darwin C (1859) On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life. John Murray, London
Dennett DC (1996) Darwin's dangerous idea: evolution and the meanings of life. Simon and Schuster, New York
Deutsch D (2011) The beginning of infinity: explanations that transform the world. Penguin Press, New York
Eckert AW (1965) The silent sky: the incredible extinction of the last passenger pigeon. Little, Brown and Company, London
Eckholm E (1986) Species are lost before they're found. The New York Times, 16 September: C1, C5
Eldredge N (1987) Life pulse: episodes from the story of the fossil record. Facts on File Publications, New York
Erlich P, Erlich A (1968) The population bomb. Ballantine Books, New York
Fletcher A (2010) Congress. In Bronsan KA (ed) Encyclopedia of American environmental history. Facts on File, New York
Frankham R (2003) Genetics and conservation biology. C R Biol 326:S22–S39
Frankham R, Ballou JD, Briscoe DA (2010) Introduction to conservation genetics. Cambridge University Press, Cambridge
Gerber L (2010) Conservation biology. Conservation biology: nature, education, knowledge 3(10):14. http://www.nature.com/scitable/knowledge/library/conservation-biology-16089256. Accessed 30 April 2014
Glasgow Herald (1845) Extinction of species by natural causes. The Glasgow Herald, 22 August (4441)
Gottlieb R (2007) Reinventing Los Angeles: nature and community in the global city. The M.I.T. Press, Cambridge
Herbert E (2005) The Darwinian revolution revisited. J Hist Biol 38(1):51–66
Johns J (1996) A brief history of nature and the American consciousness. http://xroads.virginia.edu/~cap/nature/cap2.html. Accessed 27 April 2014
Ladle RJ, Jepson P (2010) Origins, uses, and transformation of extinction rhetoric. Environ Soc 1:96–115
Lanza RP, Cibelli JB, Diaz F, Moraes CT, Farin PW, Hammer CJ, West MD, Damiani P (2000) Cloning of an endangered species (Bos gaurus) using interspecies nuclear transfer. Cloning 2(2):79–90
Lasswell HD (1970) The emerging conception of the policy sciences. Policy Sci 1:3–14
Leopold A (1949) A Sand County almanac. Oxford University Press, New York
Marx L (2012) The idea of nature in America. Daedalus 137(2):8–21
McClung RM (1993) Lost wild America: the story of our extinct and vanishing wildlife. The Linnet Books, Hamden
Melani L (2009) Renaissance: the great chain of being. http://academic.brooklyn.cuny.edu/english/melani/cs6/ren.html. Accessed 25 April 2014
Mitchell WJT (2003) The work of art in the age of biocybernetic reproduction. Modernism/modernity 10(3):481–500
Monticello.org (n.d.) Species extinction. http://www.monticello.org/site/research-and-collections/species-extinction. Accessed 24 April 2014
Moscowitz C (2012) Baby bison born via embryo transfer may boost species recovery. http://www.livescience.com/22847-bison-birth-species-conservation.html. Accessed 30 April 2014
Muir J (1912) Hetch Hetchey valley. http://www.sierraclub.org/john_muir_exhibit/writings/the_yosemite/chapter_16.aspx. Accessed 29 April 2014

National Park Service (n.d.) Theodore Roosevelt quotes. http://www.nps.gov/thro/historyculture/theodore-roosevelt-quotes.htm. Accessed 10 April 2014
Novacek MJ (2001) Preface: biodiversity. In: Novacek MJ (ed) The biodiversity crisis: losing what counts. The New Press, New York, pp 12–13
Phys.org (2012) Embryo transfer results in healthy purebred Yellowstone bison calf. http://phys.org/news/2012–08-embryo-results-healthy-purebred-yellowstone.html. Accessed 11 April 2014
Pinchot G (1910) The fight for conservation. http://www.gutenberg.org/files/11238/11238-8.txt. Accessed 1 March 2014
Portman J (2011) 5 things you need to know about the great American bison. http://www.pbs.org/wnet/need-to-know/five-things/the-great-american-bison/8950/. Accessed 29 April 2014
Raff JA, Bolnick DA (2014) Palaeogenomics: genetic roots of the first Americans. Nature 506:162–163
Renshaw G (1905) More natural history essays. Sherratt & Hughes, London
Robin L, Carruthers J (2011) Introduction: environmental history and the history of biology. J Hist Biol 44:1–14
Soulé ME (1985) What is conservation biology. BioScience 35(11):727–734
Speth JG (1989) The greening of the summit. The Washington Post, 9 July: B5
Thomson K (2011) Jefferson's old bones. The American scientist. 99(3). http://www.americanscientist.org/issues/pub/jeffersons-old-bones/1. Accessed 23 April 2014
Time (2009) Vanishing act: how climate change is causing a new age of extinction. Time, 13 April: http://content.time.com/time/covers/0,16641,20090413,00.html. Accessed 30 April 2014
Toffler A (1970) Future shock. Random House, New York
United Kingdom House of Lords (1929) Preservation of wild fauna. 75 (November):625–650. http://hansard.millbanksystems.com/lords/1929/nov/21/preservation-of-wild-fauna. Accessed 26 April 2014
United Nations Environmental Program (2014) What is biodiversity? http://www.unep-wcmc.org/what-is-biodiversity_50.html. Accessed 30 April 2014
West L (2014) Earth day history: the history of earth day. http://environment.about.com/od/environmentalevents/a/twoearthdays.htm. Accessed 30 April 2014
Williams R (1983) Keywords: a vocabulary of culture and society. Flamingo, London
Wolf, EC (1987) On the brink of extinction: conserving the diversity of life. Worldwatch Paper #78. The Worldwatch Institute, Washington, D.C.

Chapter 3
Bio-Inventories: The Digitization of Nature

Abstract This chapter analyses the bioinformatics revolution and its implications for conservation and wildlife management. Bioinformatics refers to the hardware and software that stores and analyzes the massive amount of data being generated by molecular biology today. The growth of the bioinformatics industry reflects the explosion in genomic data available to researchers in the post-Human Genome Research Project era, the steep decline in the cost of gene sequencing since the 1990s, and the recent prioritization of genomic analysis in medicine and forensics. Bioinformatics is the crucial technological scaffolding for a newly molecularized nature in which surveillance and manipulation at the genetic level begins to displace species or habitat-level interventions. This chapter begins with a discussion of bioinformatics and the twin dynamics of the digitization and molecularization of life. It then analyses the political discourse used to promote the Encyclopedia of Life before moving to an in-depth evaluation of the controversies surrounding DNA barcoding. The chapter concludes by reflecting upon digital nature, this new media space in which everything will be counted but there may be no wilderness left to enjoy.

> *All we have yet discovered is but a trifle in comparison with what lies hid in the great treasury of nature.*
>
> Antoni van Leeuwenhoek (1708)

3.1 They Had to Count Them All: Bioinformatics and DNA Barcoding

Bioinformatics is the "field of biology which develops hardware and software to store and analyze the huge amounts of data being generated by life scientists" (National Institute of General Medical Sciences 2010, p. 85). The field weaves together insights and concepts from disciplines such as statistics, mathematics, chemistry, biochemistry, physics, and linguistics. It focuses on three levels of analysis: (1) analysis of a single gene (protein) sequence; (2) analysis of complete genomes; and (3) analysis of genes and genomes with respect to functional data (Kumar 2005). The recent growth of the bioinformatics industry reflects the explosion in genomic data now available to researchers in the post-Human Genome Research Project era, the steep decline in the cost of gene sequencing since the 1990s, and the recent prioritization of genomic analysis in medicine and forensics. For example, the National

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Human Genome Research Institute (NHGRI) tracks the cost of DNA sequencing undertaken at centers funded by its research grants. Since 2001, the cost to sequence a human-sized genome (containing over 3 billion base pairs) has decreased from $100 million to less than $10,000 USD (NHGRI 2014).

Bioinformatics is the crucial technological scaffolding for a newly molecularized nature in which surveillance and manipulation at the genetic level begins to displace species or habitat-level interventions. This chapter begins with a discussion of bioinformatics and the twin dynamics of the digitization and molecularization of life. It then analyses the political discourse used to promote the Encyclopedia of Life before moving to an in-depth analysis of the controversies surrounding DNA barcoding. The chapter concludes by reflecting upon digital nature, this new media space in which, though everything may be counted, some fear there may be no unmediated nature left to enjoy.

3.2 Cracking the Code of Life: Bioinformatics in the Twentieth Century

The recent emergence of the bioinformatics industry represents the apotheosis of the mid-twentieth century's vision of life as a form of code. The fields of biology and information science began to merge systematically in the Cold War research labs of the 1940s and 1950s. The metaphor of DNA as the code of life proved especially powerful to the twentieth century scientific and industrial imagination following the crucial breakthrough of James Watson's and Francis Crick's elucidation of the DNA double-helix model. In 1962, Watson, Crick and Maurice Wilkins received the Nobel Prize in Physiology or Medicine "for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material" (Nobelprize.org 2014). This new paradigm of how DNA was organized within the cell and how information could be passed through the generations quickly crossed from elite scientific circles to the mainstream. For example, in 1963, *Life International* magazine featured an extensive cover story on DNA (discussed in-depth in chap. 4), referring to it as "the keeper of the code for all life everywhere" (Life 1963, p. 40) and to molecular biology as "the most exciting frontier in all of science today" (Hills and Rosenfield 1963, p. 45). The magazine stressed the futuristic implications of molecular biology for insights into human health and the possible forestallment of the aging process. By the 1980s, when initiatives such as "frozen zoos" (repositories of endangered species tissue samples) and large-scale species inventories began to be envisaged and publicly promoted, the idea that DNA was biological software, that "DNA can be viewed as a massive computer program" (Young 1991), was entrenched in both scientific and popular discourse. It became so fundamental to the life sciences project and to how we look at the natural world that it is difficult now to consider alternative metaphors or frameworks: the idea of life as code seems to our culture to be the literal description of how things are.

The integration of biology and information science accelerated following the launch of the Human Genome Project in the 1980s and the subsequent imperative to store, process and analyze massive amounts of genetic data linked either to individuals or population cohorts, via health-related or forensic DNA databases. Dozens of mammalian species have since been sequenced, as scientists attempt to decipher the information contained in each genome and to compare these for insights into evolutionary patterns and adaptations. For example, a project recently launched (2013) by a consortium of institutions including Illumina, Inc. and Qinghai University plans to sequence the polar bear, emperor penguin and the Tibetan antelope, all of them considered extreme-environment species that will provide unique insights into adaptation under severe climatic conditions. Social scientists tend to focus on the ethical, legal, and social implications (ELSI) of these databases, with an emphasis on data privacy, while critical analysts contend that the convergence of biological and information technologies generates new possibilities for political power and economic organization. Nikolas Rose, for instance, refers to contemporary biology as a "flattened field of open circuits" in which molecular information endlessly circulates and recombines into new forms and products (Rose 2007, p. 7). For W. J. T. Mitchell, "the convergence of genetic and computational technologies with new forms of speculative capital has turned cyberspace and biospace, the inner structure of organisms, into frontiers for technical innovation, appropriation, and exploitation" (Mitchell 2003, p. 481).

The synergy between advances in information technology and the growth of the genomics industry facilitates what Nikolas Rose (2001) calls molecularization, the process by which life is "imagined as sub-cellular processes and events, controlled by a genome which is neither diagram nor blueprint but a digital code written on the molecular structure of the chromosome" (pp. 13, 14). Enabled by biotechnology, both science and society began to shift in the late twentieth century from a focus on the whole organism/body to the fragment/gene. The result of this shift is that biological processes such as aging and illness (and potentially extinction) are increasingly conceptualized as information processing problems in which genetic programmes can be de-coded and then potentially rewritten to unwind along human-directed paths rather than natural ones. Such a shift in perspective is only possible in a cultural moment that privileges the discourse of the digital. For example, when Jerome McGann, a proponent of digital humanities and the founder of the Rossetti Archive, exults that "the whole of our cultural inheritance has to be recurated and reedited in digital forms and institutional structures" (Kirsch 2014), he isn't simply indulging in hyperbole. Rather, he reflects a worldview, increasingly common in science and in the culture, in which the twin forces of molecularization and digitization are both inevitable and irresistible.

Molecularization in health and medicine enables new ways to regulate and treat human and animal bodies, such as human gene banks and personalized medicine. It also introduces a potential new source of wealth referred to by scholars as *biovalue,* meaning the surplus of vitality created by biotechnologies such as stem cells and oocytes (Waldby 2002). The generation of biovalue can yield public benefits in the form of new medical treatments, though Catherine Waldby focuses on the corporate

incentive to develop new companies and tradable biotechnological commodities by exploiting the reserves of information contained in genes (Waldby 2002).

Ultimately, the global economic system enabled by molecularization represents the triumph of molecular biology and genetics over physics and chemistry as the dominant explanatory frameworks for twenty-first century investigations of biological life (Braun 2007). Edwin Schrodinger anticipated this shift as early as 1944, when he lauded the biologists and geneticists for their discovery of the material structure of organisms and contrasted these breakthroughs with the inability of physics and chemistry to explain "what happens in space and time within a living organism" (Schrodinger 1944, p. 2). Since the early 1990s, the social scientific analysis of molecularization has produced a rich literature on human health and illness. The following discussion draws upon these insights, but shifts focus to an analysis of what I term biocybernetic nature and the implications of molecularization and digitalization for how we understand nature and respond to the extinction crisis. For example, Waldby argues, referring to embryonic stem cells and oocytes, that "biotechnology tries to gain traction in living processes, to induce them to increase or change their productivity along specified lines, intensify their self-reproducing and self-maintaining capacities" (Waldby 2002, p. 310). This insight provides a framework for evaluating the parallel relationship between biotechnology and conservation and the importance of such vital fragments as the CO1 gene region used in DNA barcoding or the ancient DNA specimens that contain information about the environmental past (discussed at length in chap. 5). The following section begins this analysis by focusing on the Encyclopedia of Life as a bio-informatic initiative with significant cultural implications.

3.3 The Encyclopedia of Life

Though he had proposed the idea four years earlier (Wilson 2003), the famed Nobel laureate and entomologist Edward O. Wilson brought the Encyclopedia of Life into the mainstream with his acceptance speech for a T.E.D prize in 2007. As noted in chap. 2, Wilson had begun urging Governments to support a global inventory of life in the 1980s. The *New York Times* described his mission then as a "new age of exploration, a crash effort to find and study millions of species before they are wiped out" (Eckholm 1986, p. C1). Thirty years later, his T.E.D. speech drew again upon the facts and rhetoric of the extinction crisis, while it also deployed the resonant metaphor of a "biological moonshot with a timetable" (Wilson 2007) to generate a sense of optimism and urgency about the species inventory initiative. Wilson used the acronym "HIPPO" to describe the anthropogenic forces converging in the modern era to destroy our ancient biosphere: habitat destruction; invasive species; pollution; population; and over-harvesting. He warned that "we are, in short, flying blind into our environmental future. We urgently need to change this. We need to have the biosphere properly explored so that we can understand and competently manage it.

We need to settle down before we wreck the planet. And we need that knowledge" (Wilson 2007).

In one sense, not much had improved with respect to the extinction crisis over the thirty years separating Wilson's T.E.D. speech from his earlier article in *The New York Times*; indeed, things had arguably gotten considerably worse. In the United States alone, for example, approximately 15 % of the species known to science have been evaluated carefully enough to determine their conservation status. Of that 15 %, approximately 20 % are already perilously close to extinction (Wilson 2007). What *had* changed remarkably in those three decades was technology, specifically information technology and biotechnology. The Encyclopedia of Life proposal was based on a simple, elegant and timely idea: creation of an electronic web page for every species. As Wilson envisioned it, the EOL would be "an encyclopedia that lives on the Internet and is contributed to by thousands of scientists around the world. Amateurs can do it also. It has an indefinitely expandable page for each species" (Wilson 2007). Though three hundred years had elapsed since the Swedish zoologist Carl Linnaeus first developed a classification system that still organizes taxonomic knowledge today, only 60,000 species are known to science, while an estimated 1.5 million wait to be discovered (Wilson 2007). At the start of the twenty-first century, what R.S. Deese refers to as the "cybernetic principle of viewing physical systems as information" (2009, p. 74) seemed to have reached fruition in the EOL idea and only just in time.

In 2008, the EOL officially began gathering new taxonomic information and aggregating content from partner initiatives such as FishBase, Tree of Life (TOL) Web Project, and AmphibiaWeb. As described in its promotional material, the EOL "is a sweeping global effort to gather scientific knowledge about all living things into a single online resource, giving each of us a breathtaking view of living nature" (EOL n.d.). The website today is extraordinarily rich. It makes freely available much of the world's biodiversity literature, provides free materials for students, schools and citizen scientists, and continually generates and curates new knowledge about global biodiversity. Anyone with access to the Web can easily register for an individual account and upload both taxonomic information and digital images. Though the goal of harnessing the participation of individuals and communities is essential to the initiative, a volunteer group of scientific experts ensures the quality of the biodiversity information provided by participants by authenticating it before it is uploaded to the site. Digital data flows to the EOL in a steady stream and includes descriptions, photos, distribution maps and even rare and specialized information. Major funders of the initiative have included the John D. and Catherine T. MacArthur Foundation and the Alfred P. Sloan Foundation, as well as the Andrew W. Mellon Foundation, the Global Biodiversity Information Facility (GBIF), the National Geographic Society, and the Museum of Comparative Zoology at Harvard. Individual donations of any size are also accepted and some public funding is provided via the annual U.S. Congressional appropriation to the Smithsonian Institution.

The Encyclopedia of Life has already enhanced access to taxonomic information among both specialists and amateur conservationists, since at the push of a button those connected to the Internet can find an extraordinary amount of data, resources

and stunning digital images of species. Still, as Dorothy Nelkin (2001) reminds us, "all reference works are the product of cultural choices, reflecting social perspectives on the world at the time of their making" (p. 558), while Iina Hellsten emphasizes that the metaphors used in environmental initiatives promote particular viewpoints on science and nature (Hellsten 2002). The EOL as a cultural choice merits closer analytical attention because it tells us something important about our relationship to nature and to technology at this historical juncture. As a metaphor, the "encyclopedia of life" is simple, powerful and instantly recognizable to a significant portion of the population. It also embodies Marshall's McLuhan's dictum that new media technologies paradoxically render previous forms obsolete while also drawing upon those earlier forms for cultural legitimacy (Kroker and Kroker 2010). The name "encyclopedia of life" links this quintessentially twenty-first century project to the dusty old print encyclopedias so popular in American homes during the Cold War, at the same time that its structure reinforces this moment's cultural and economic shift from print to digital representation and thus from the tangible artifact to the disembodied data stream. Moreover, the idea that the proliferation of digital images and information will correspond to a significant new push from the general public for stronger biodiversity preservation tells us more about what we wish for than what we actually know.

The EOL initiative deploys multiple metaphors within its reports, press releases and on its website to persuade the public to support this multi-year, large-scale initiative. For example, the opening statement of the 2009 annual report by oceanographer Sylvia Earle (a T.E.D. prize winner and a member of EOL's advisory board) notes the distressing fact that "it took more than 4 billion years to transform lifeless rocks and water into an astonishingly diverse paradise, and less than a century to destroy thousands of species that make it prosper" (EOL 2009). Yet against this dismal backdrop, the majority of the document is a technophile's manifesto in which new technologies, used wisely, are presented as the key to unlocking the knowledge—and the political will—necessary to halt the extinction crisis. For example, the EOL is described as a 'macroscope' with the "power to identify hitherto unrecognized biodiversity principles and patterns," generating knowledge that will, we are told, increase "public understanding of this precious and fragile world" (EOL 2009, p. 2). Yet even a strong proponent of the EOL (like myself) might reluctantly note that no evidence is provided by this most sophisticated of scientific initiatives to bolster the assertion that ready access to species information increases the average person's appreciation of biodiversity. Instead, the taxonomist's assumption that information is an intrinsic good with both scientific and political value underwrites the project and its appeals for support without question.

The EOL also attempts to re-enroll the amateur naturalists of the nineteenth century who were left behind when taxonomy, like other scientific disciplines, professionalized in the twentieth century. Thomas Gieryn (1983) analyses the way in which the current prestige of many scientific fields required intense boundary-work, defined as "an ideological style found in scientists' attempts to create a public image for science by contrasting it favorably to non-scientific intellectual or technical activities" (p. 781). Once the Cold War began and scientific expertise became a key

marker of superpower pre-eminence, the type of gentleman naturalist embodied by Charles Darwin became quaint relics of a gentler century. Increasingly, the public was barred from scientific debates, which became ever more rarefied and elitist, while at the same time it was expected to support the science industry with large and unquestioned appropriations of public money. Today, as science increasingly corporatizes and public funding decreases, there is a new need to open up the lab, to invite the public in as sponsors and collaborators. The EOL leverages this new discourse of participatory science when it argues that its programs for young pupils "encourage children to grow up appreciating nature and to become active, life-long citizen scientists" (EOL n.d.).

The idea that EOL is a citizenship project, wherein we can enact our responsibility for biodiversity and conservation by uploading data and interacting through social networks, permeates most of the publicly available documents on the initiative. In light of the extinction crisis, the hope is that initiatives like EOL will encourage robust links between the individual, society and nature. The problem is that this claim needs to be substantiated, particularly in light of the alternative theory that substituting digital for actual nature only exacerbates a fundamental cultural alienation from the wilderness (Schulman 2011). Whether an electronic encyclopedia of life enhances or depresses the average citizen's concern for actual endangered species would seem to be a question of the utmost importance to a project like the EOL. Just as an old-fashioned encyclopedia could enhance learning only if the books were opened and read, an online "encyclopedia of life" will not automatically connect information to politics and cannot provide complete answers to the wicked problems of habitat destruction, over-population and climate change.

3.4 A Barcode for Every Species

The Encyclopedia of Life is technologically sophisticated and raises important philosophical questions about our relationship to the natural world, but ultimately it reflects the digitization of the familiar idea of the compendium. DNA barcoding, another recent bioinformatics application, is much more controversial both because it challenges traditional taxonomy as a profession and further reifies the cybernetic vision of nature as information. Professor Paul Hebert, a population geneticist at the University of Guelph in Canada, introduced his version of a DNA barcode in 2003. While the use of DNA barcodes in the plant kingdom proved more difficult than originally anticipated, the scientific standard for the mammalian barcode is now a 645 base pair region of the mitochondrial COX1 gene (cyotochrome c oxidase subunit 1). This region is both highly variable across species and highly specific within them: in other words, advocates argue, the barcode constitutes a statistically reliable biomarker for distinguishing one species from another.

Following a preliminary presentation on Hebert's research, the Sloan Foundation donated $1 million USD to establish the Consortium for the Barcode of Life. Subsequently, the Gordon and Betty Moore Foundation donated an initial $3 million USD to

the effort to churn out species barcodes in high volume. Large-scale DNA barcoding initiatives such as the Barcode of Life (BOL) integrate the Internet, global positioning systems (GPS) and other relatively inexpensive digital devices with barcode identification in order to manage the amount of data now available for environmental policy and wildlife management decisions. The claims made about DNA barcoding and its significance often make those for the EOL seem comparatively modest. For example, the Royal Ontario Museum (2009) contends that "barcoding promises to massively advance our capacity to monitor, understand and manage biodiversity with profound societal and economic implications. Once fully implemented, this system will revolutionize access to biological information and will advance research policy, pest and disease control, food safety, conservation, and many other areas."

Bioinformatics in conservation looks backwards to classical taxonomy for inspiration and to the digital future for legitimization. Indeed, though it draws upon cutting-edge technology, DNA barcoding as an idea places us squarely back in the Enlightenment. It embodies a worldview which equates information with power, in this case the power to influence stakeholders to value and to save biodiversity. DNA barcoding has an explicit political dimension, in that its advocates contend that it will also empower and energize amateur conservationists, such as hikers, hunters, and tourists, to become foot soldiers on the front lines of the extinction crisis, able to upload accurate and urgent data about species to the global environmental grid. Like the EOL, public appeals for support of DNA barcoding and its associated initiatives repeatedly emphasize the role of these "citizen scientists," the new soil soldiers and tree troopers of the digital age. Perhaps most importantly, the discourse of DNA barcoding reframes the rhetoric of environmental catastrophe into a call for action and engagement, with completion of the all-species-inventory of Earth's biodiversity the new frontier awaiting our investigation. Nevertheless, analysis of the debate that surrounds DNA-barcoding indicates, as discussed in the sections below, that the simple equation of biodiversity information with political action may not be as compelling as its advocates contend.

3.4.1 Transforming Ecology: From Species to Genes

As noted in chap. 2, by the late twentieth century, the political defense of biodiversity increasingly revolved not around appeals to the intrinsic value of nature but instead around the argument that a healthy ecosystem provides crucial services to humanity. Subsequently, alongside the DNA-as-code metaphor, species began to be conceptualized as sources of valuable genetic information. The *New York Times*, for example, argued that "each species, whether charming to most humans or not, is a unique repository of enormous genetic and ecological information" (Eckholm 1986, p. C6). The elision of the concepts of species and information in turn facilitated two important developments. First, the sheer amount of genetic data now available transformed "ecology from a species-based to a gene-based view [which is] much closer to how the biological world actually works" (Caddy-Retalic and Lowe 2012). Secondly, the

species-as-data worldview dovetailed with the rise of the genomics industry and the corporate search for patentable genes that could be used in new pharmaceutical products. As Thomas E. Lovejoy of the World Wildlife Fund argued, "natural species are the library from which genetic engineers can work. Genetic engineers don't make new genes; they rearrange existing ones" (Eckholm 1986, p. C5). The generation of biovalue thus linked barcoding-as-conservation and barcoding-as-innovation.

Lovejoy's point about scientists not making new genes may no longer be quite as accurate as it was in the 1980s, as will be discussed in chap. 6. Nevertheless, the observation anticipates a tension in the DNA barcoding mission that endures today: the same technology that facilitates rapid species identification and citizen participation in conservation also facilitates the global race to isolate and lock-down biovalue in the form of patented genes. Ironically, the knowledge enabled by DNA barcoding can potentially endanger an already vulnerable or valuable species (according to the same logic by which global-positioning systems can be used by both conservationists and poachers). The conflict between identification and commodification can become so acute that those who collect biodiversity information find themselves invoking an informal norm of "rare species confidentiality" to prevent hordes of tourists and collectors from exploiting a newly re-discovered and fragile species (Witcher 2010). While the rationale behind this seems ethically unassailable at first glance, expert-invoked confidentiality about species' locations coexists uneasily with the emphasis on public engagement that underwrites proposals to fund digital species inventories and their associated technologies.

3.4.2 The Taxonomic Impediment

Carolus Linnaeus published *Systemae Naturae* in 1735. It remains the foundation text of the Western scientific classification of plants and animals, with the categories of kingdom, phylum, class, order, family, genus and species being familiar to most middle-school biology students. Aristotle had developed a system that distinguished vertebrates (blooded) from invertebrates (bloodless) and can be considered the first Western systematist. Linnaeus's scheme, however, both embodied and propelled the European Enlightenment, with its emphasis on order, systematization of knowledge, and exploration. Taxonomy, like the wonder cabinets, botanical gardens and menageries emerging in Europe in Linnaeus's time, celebrated the spirit of curiosity believed to motivate science at its finest. Three hundred years later, DNA barcoding emerges in a less confident age, when the taxonomic imperative to find things before they disappear seems both increasingly urgent and doomed to failure.

In the late twentieth century, based on estimates that less than 5 % of the earth's living creatures were then known to science, *Whole Earth* magazine picked up E.O. Wilson's call for an all-species inventory initiative to catalogue all of the earth's diversity within one human generation (Kelly 2000, p. 4). DNA barcoding was initially applauded by environmental activists as the technological route to this goal precisely because it significantly decreases the amount of time that it takes to identify

species, while exponentially increasing the amount of genetic information that can be gathered, analyzed and stored. Paul Hebert and T. R. Gregory evoked the spirit of the Enlightenment when they argued that DNA barcoding will make the Linnaean taxonomic system more accessible, with benefits to ecologists, conservationists, and the diversity of agencies charged with the control of pests, invasive species, and food safety (Hebert and Gregory 2005, p. 852). Moreover, as Knudsen argues, "successful scientific communication relies on the intended meaning of concepts being communicated precisely, clearly and convincingly" (Knudsen 2005, p. 376). In this respect, the DNA barcode metaphor was extraordinarily successful. Like most things in science, Paul Hebert's idea, though significant, was not entirely new. Earlier attempts to promote DNA-based identification methods for species (DeSalle and Berstein 1996) failed to ignite much interest in either the scientific community or the mainstream media (Cameron et al. 2006). Hebert expertly introduced barcoding to the public in a *New York Times* article titled "A Species in a Second," putting it in context that virtually anyone could understand when he said that "in a grocery market it occurred to me that we have minimal diversity in universal product codes, yet we can distinguish all these products" (Wade 2004). The analogy was tailor-made for both the mainstream media and the general public, who could now envision the Earth as one giant warehouse full of species that needed to be inventoried. The Consortium for the Barcode of Life (CBOL n.d.) admits on its webpage that the DNA barcode metaphor is not accurate in its finest details but is nevertheless useful and illustrative. The mass media and DNA barcode advocates were also quick to employ familiar science fiction references to describe the power of this new approach to species identification. For example, Nicholas Wade opened the article in which Hebert offered the grocery store analogy by asking, "when an astronaut sets foot on an alien planet and sees moving shadows in a nearby wood, he whips out a scanning device that immediately identifies the menacing life-form... If such devices are standard equipment for visiting distant planets why can't we have them here at home where we really need them" (Wade 2004)? Similarly, several articles compared DNA barcoding to the Tricorder, famously used on the television series *Star Trek* for instantaneous sensory scanning and data analysis on alien planets.

Taxonomy, a science that deals with the description, identification, naming and classification of organisms, is obviously essential to biodiversity management. As F. Cotterill argues, "taxonomies provide the channels to communicate accurate information from the original sources of all biological investigations; taxonomies, and the methodologies which construct them, are information-processing systems" (1995, p. 229). Yet the practice of taxonomy is inextricably bound up with the history of technology, from printing to lenses to digital media, and with the development of professional communities in the nineteenth and twentieth centuries. Consequently, for all of its potential contributions to biodiversity preservation, DNA barcoding initially encountered fierce opposition among the taxonomic profession because it seemed to threaten both how and why taxonomy was traditionally done. Advocates tried hard to cast DNA barcoding as both a revolutionary advance worth of significant public and private investment and as a link to taxonomy's storied history. For example, W. John Kress, a research botanist and curator at the National Museum of Natural

History (Smithsonian), compares the participatory spirit of the digital DNA species inventories to the National Audubon Society's Christmas bird counts, an initiative begun in 1900 which encourages average citizens to help count bird species and track migration and distribution patterns in order to inform conservation priorities (Kress 2010; National Audubon Society 2014). Advocates argued that social media, far from undermining the direct experience of nature, instead could revitalize it and make taxonomy meaningful to a new generation. As Lee Weight (2010), Director of the Laboratories of Analytical Biology at the Smithsonian Institution argues, "if I'm a high school kid or a college kid. . . everything is mobile devices, everything is computer driven. All those people complaining about that did not have computers in graduate school. So, now everyone does. They don't want to cast them aside. They want to leverage them and be ready for whatever is coming next on them. There is an app for that. There is an app for describing a species. It should be that simple. It can be."

For critics, however, DNA barcoding emerged in the midst of a crisis wherein taxonomy appeared to be losing its salience in the new era of Big Science and large-scale initiatives like the Human Genome Project. As early as the 1980s, traditional taxonomists feared that "dramatic progress in molecular biology has stolen status and resources from the task of describing and comparing different forms of life" (Eckholm 1986, p. C1). Twenty-five years later, scientist W. J. Kress noted that he had received more funding for barcoding work than he had ever received for anything else in his professional career as a scholar (Kress 2010). The so-called taxonomic impediment refers to a convergence of contemporary problems in the profession, including the "length of time it takes to identify species; the reliance on phenotypic characteristics; the problem of bias; and difficulty of locating taxonomic literature" (Costa and Carvalho 2007). Moreover, as Katja Schultz, species page coordinator for the Encyclopedia of Life at the Smithsonian Institution, argues "right now this basic taxonomic work is incredibly tedious and then on top of that part of the crisis is the fact that there aren't any jobs for taxonomists. There are very few. Considering the amount of work that needs to be done, the number of jobs that are being offered is just miniscule" (Schultz 2010).

The taxonomic impediment, coupled with a pervasive fear that taxonomy now seemed to outside observers like a fusty old relic of the non-digital age, caused many taxonomists to balk at the idea that a single gene region and a cheap electronic scanner could replace the painstaking training and expertise upon which traditional taxonomy relied. In a retrospective analysis of DNA barcoding's first decade, Dirk Steinke reminds us that the research article by Paul Hebert (et al. 2003) that introduced DNA barcoding to a scientific audience, though it is now a keystone publication that has been cited more than 2500 times, was initially rejected by peer reviewers. Moreover, those "reviews were harsh, sometimes on the brink of being offensive, but they were just the overture to a series of anti DNA barcoding publications indicative of the strong antagonism the idea provoked" (Steinke 2013, p. 2). Of course, the language that DNA barcoding advocates used often encouraged resistance at first, particularly in a profession already sensitive to the stereotype that it was not real science but "mere stamp collecting" (Cotterill and Foissner 2010, p. 298). Paul Hebert justified

the need for rapid uptake of the COX1 standard by arguing that "taxonomic expertise is collapsing" (Hebert et al. 2003, p. 313). DNA barcode advocates also leveraged the rhetoric of crisis—in this case, an urgent lack of time—to argue for a technology-enabled revolution in taxonomic practice. One study estimated that "a significant increase in the rate of characterization of the protists will require at least 284 protist specialists to describe five new species a year, if 35,000 species are to be described within 25 years" (Cotterill and Foissner 2010, p. 297). The warning contained in such estimates is that, given the dwindling numbers of students choosing to study taxonomy and the limited financial resources available to the profession, acceptance of DNA barcoding as standard practice would be the only way to complete the catalog of life before it vanished altogether and to save the taxonomic profession from extinction.

3.5 Digital Natures

The recent surge in the availability and ubiquity of social media platforms such as Facebook©, MySpace© and Twitter© provides both the means and the incentive for various scientific fields to digitize. Bioinformatics, when merged with accessible and relatively inexpensive devices such as cell phones, provides a way to enroll the public as ostensible scientific peers who can contribute crucial information to species identification. In this sense, bioinformatics is a twenty-first century technological adaptation that returns modern biology to its roots in the nineteenth century tradition of the amateur naturalist. Bioinformatics in conservation also dovetails with a recent emphasis in social science on the need to relinquish the deficit model of the public understanding of science (in which scientists educate the public via the top-down presentation of facts) in favour of a peer-to-peer model in which citizens, policy-makers and scientists interact as equals. If the "central theme of environmental politics over the last four decades has been the effort to change where decisions are made: not within these closed [scientific] worlds, but in the public view" (Bocking 2004, p. 23), then social media seems to be the perfect technological conduit to a truly participatory environmentalism.

Yet we need to consider the fact that what might be called the participation imaginary has animated environmentalists for decades without necessarily stopping the extinction crisis (though it may have prevented it from being even worse). For example, Ralph W. Schreiber, former Curator of Ornithology at the Los Angeles Natural History Museum (LANHM) from the 1970s, is remembered today for introducing important changes to improve the visitor's experience of the exhibits. He believed "that if people could 'participate' with an exhibit they would not only learn to appreciate the incredible diversity of birds, but would also gain a new understanding of the world around them and want to preserve it for future generations" (LANHM 2012). My point is not to criticize such aspirations. The biodiversity that we can still appreciate today may largely be due to the efforts of curators and conservationists

such as Schreiber; indeed the link between museums and environmental awareness is a topic that merits several books of its own. Yet what we do not know with any degree of certainty is whether or not museum exhibits, encyclopedias of life, or DNA barcoding can reach people who would not otherwise be interested in biodiversity; in other words, what is problematic is not the goal of remaining current with new technologies, but the underlying assumption that the provision of information translates into action by the non-enrolled and non-committed. If, as critics of DNA barcoding contend, habitat preservation is the only real way to preserve species over the long haul, then much of the funding that flows to digital initiatives may even be seriously misallocated.

Conservation bioinformatics is embedded in global context characterized by the rhetoric of crisis. These new technologies and the perceived urgency and inevitability of their use cannot be isolated from the fact that the anthropogenic extinction crisis confront societies on an unprecedented level. They emerge at a time in which many traditional taxonomists fear that the discipline itself is facing severe loss of expertise as retiring professionals are not being replaced by adequate numbers of trained graduate students and junior professors (Blaustein 2009 and Wilson 2004). Finally, conservation genetics, the professional field for which DNA barcode knowledge is probably most relevant, defines itself as a "crisis discipline" characterized by its use of new molecular and information technologies to save "the large number of species facing imminent extinction" (DeSalle and Amato 2009, p. 3). Of course, the interaction between technology, society and nature is not new; indeed, it is the defining feature of modernity. Etienne Benson, for example, argues that radio-tracking, which began to be used by American wildlife managers in the 1950s, "reflected a new, postwar vision of nature made manageable through advanced technologies of surveillance and control" (Benson 2008, p. 30; see also Mitman 1996 and Haraway 1992).

Nevertheless, the rapid proliferation of bioinformatics in environmental policy will affect the ways in which humans conceptualize and interact with nature and wilderness, while also changing the relative prestige of specific fields and professional communities within the broadly-defined conservation community. Today's DNA barcodes and web-based encyclopedias are a new and significant stage in the use of what Benson (2008) refers to as technologies of legibility, those means by which we make nature visible. The idea that digital technology can render the biodiversity crisis visible to the general public is therefore a consequential claim. Paul Hebert states that, "once established, this microgenomic identification system will overcome the deficits of morphological approaches to species discrimination: the bounds of intraspecific diversity will be quantifiable, sibling species will be recognizable, taxonomic decisions will be objective and all life stages will be identifiable" (Hebert et al. 2003, p. 320). It seems churlish to oppose or even to critique such a technological breakthrough, but unfortunately the political problems of habitat loss and overpopulation remain even in this bar-coded world. DNA barcodes will provide valuable information about illegal trade in wildlife, vulnerable habitats and populations, but barcodes alone cannot change the economic dynamics and cultural

blinders that encourage a global black market in endangered species or the ongoing development of land. Ultimately, there is no reliable bridge between information and compassion or between information and political action that knowledge, by itself, can construct. We have to create those links ourselves with as much attention to the politics of extinction as to the processes of it.

To conclude, it is a well-established tenet of the postmodern critique of Western environmentalism that "nature has come to an end both as an uncharted space 'out there' (the modernist-frontier concept) and as a calculable, law-like referent we can sail by like a navigator sails by the East" (Flitner and Heins 2002, p. 324). Yet the quick rise of DNA barcoding—and the species inventories associated with it—suggests that not everyone concurs with this assessment. DNA barcoding, like the cloning of endangered species to be discussed in the next chapter, reclaims and rehabilitates the modern ethos of curiosity and exploration. DNA barcoding's advocates envision nature as full of new frontiers awaiting our exploration through the tools of social media. Hebert and Gregory, for example, claim that "DNA barcoding allows a day to be envisioned when every curious mind, from professional biologists to schoolchildren will have easy access to the names and biological attributes of any species on the planet" (Hebert and Gregory 2005, p. 852). That day, of course, is in the future, where there is hope, just as Hebert's work has been described as "a good reminder the crises in the headlines are really all about the past. His work is all about the future" (Wente 2008).

The postmodern environmental critique therefore has not superseded the modernist scientific imaginary; instead, it runs parallel to it, which helps to explain why environmental disputes remain so intractable in the contemporary era. Those who still believe in the power of science to correct the destructive path we are on and those who are skeptical that anything like untrammeled depoliticized information still exists continue to talk past each other while the extinction crisis persists. The majority of us, I expect, are caught in the middle, sympathetic to the need for more biodiversity information yet wary of the implications of a fully digitalized nature in which nothing is left alone or uncounted. Ellis and Waterton (2004), in an analysis of a British DNA barcode project, identify a tension between science and society, "between data gathering and the experiential vision of participation" (p. 98). More evocatively, in an article entitled "GPS and The End of the Road," Ari Schulman (2011) laments the coming of this digitized world in which "the GPS-enabled, location-aware adventures of Sal and Dean or Huck and Jim somehow sound dreary before they have begun, filled with anticlimax, boredom, and restlessness. How can this be, when what these technologies seem to promise is a way of freshly opening up the world" (p. 20). For all of the good it might do, the danger of DNA barcoding, as with bioinformatics in conservation writ large, is the possibility that once we've counted everything, there won't be any surprises—nothing new, mysterious, dangerous, or unexpected—left in nature, indeed there may be nothing natural or wild left at all. Perhaps, as Christopher Lloyd (2010) suggests, we need to stop "this crazy business of counting species" and redirect our focus to political and habitat-level interventions that might actually heal the planet before it is too late.

References

Benson ES (2008) The wired wilderness: electronic surveillance and environmental values in wildlife biology. Dissertation, Massachusetts Institute of Technology

Blaustein R (2009) The Encyclopedia of Life: Describing species, unifying biology. BioScience 59(7):551–556

Bocking S (2004) Nature's experts: science, politics and the environment. Rutgers University Press, New Brunswick

Braun B (2007) Biopolitics and the molecularization of life. Cult Geogr 14:6–28

Caddy-Retalic S, Lowe A (2012) DNA barcoding: a better way to discover species. The Conversation, 5 March. http://theconversation.com/dna-barcoding-a-better-way-to-discover-species-4933. Accessed 20 April 2014

Cameron S, Rubinoff D, Will K (2006) Who will actually use DNA barcoding and how much will it cost. Syst Biol 55(5):844–847

Costa FO, Carvalho GR (2007) The barcode of life initiative: synopsis and prospective societal impacts of DNA barcoding of fish. Genomics Soc Policy 3(2):29–40

Cotterill FPD (1995) The second Alexandrian tragedy, and the fundamental relationship between biological collections and scientific knowledge. The value and valuation of natural science collections. Proceedings of the International Conference, edited by J. R. Nudds and C. W. Pettitt, The Geological Society of London, Manchester

Cotterill FPD, Foissner W (2010) A pervasive denigration of natural history misconstrues how biodiversity inventories and taxonomy underpin scientific knowledge. Biodivers Conserv 19:291–303

Deese RS (2009) The artifact of nature: 'spaceship earth' and the dawn of global environmentalism. Endeavour 33(2):70–75

DeSalle R, Birstein VJ (1996) PCR identification of black caviar. Nature 381:197–198

DeSalle R, Amato G (2009) The expansion of conservation genetics. In: Amato G, DeSalle R, Ryder OA, Rosenbaum HC (eds) Conservation genetics in the age of genomics. Columbia University Press, New York, pp 3–23

Eckholm E (1986) Species are lost before they're found. The New York Times, 16 Sept.:C1, C5

Ellis R, Waterton C (2004) Environmental citizenship in the making: the participation of volunteer naturalists in UK biological recording and biodiversity policy. Sci Public Pol 31(2):95–105

Encyclopedia of Life (2009) Imagine a website for every species: Annual Report 2008–2009. Available from http://eol.org/files/pdfs/press/EOL_Annual_Report_2009.pdf. Accessed 2 September 2014

Flitner M, Heins V (2002) Modernity and life politics: conceptualizing the biodiversity crisis. Polit Geogr 21:319–340

Gieryn TF (1983) Boundary-work and the demarcation of science from non-science: strains and interests in professional ideologies of scientists. Am Sociol Rev 48(6):781–795

Haraway DJ (1992) Primate visions: gender, race and nature in the world of modern science. Verso Books, Brooklyn

Hebert PDN, Gregory TR (2005) The promise of DNA barcoding for taxonomy. Syst Biol 54(5):852–859

Hebert PDN, Cywinska A, Ball SL, deWaard JR (2003) Biological identifications through DNA barcodes. Proceedings of the Royal Society of London B 270:313–321

Hellsten I (2002) The politics of metaphor: biotechnology and biodiversity in the media. Dissertation, University of Tampere. http://tampub.uta.fi/bitstream/handle/10024/67206/951-44-5380-8.pdf?sequence=1. Accessed 6 May 2014

Hills A, Rosenfeld A (1963) Nearer now! Control of aging and heredity. Life Int 35(9):45–50

Kelly K (2000) All species inventory. Whole Earth Catalog 102:4–10

Kirsch A (2014) Technology is taking over English departments. New Republic, 2 May. http://www.newrepublic.com/article/117428/limits-digital-humanities-adam-kirsch. Accessed 11 May 2014

Knudsen S (2005) Communicating novel and conventional scientific metaphors: a study of the development of the metaphor of genetic code. Public Underst Sci 14:373–392
Kress WJ (2010) Interview with Amy L. Fletcher, Smithsonian Institute, National Museum of Natural History, Washington, D.C., 22 January 2010
Kress WJ, Erickson DL (2008) DNA barcodes: genes, genomics and bioinformatics. PNAS 105(8):2761–2762
Kroker A, Kroker M (2010) Code drift: essays in critical digital studies. Ctheory.net. http://www.ctheory.net/articles.aspx?id=633. Accessed 7 May 2014
Kumar S (2005) Bioinformatics web. http://bioinformaticsweb.net/. Accessed 5 May 2014
LANHM (2012) Commemorative exhibit for Ralph W. Schreiber, Hall of Birds. Visited by Amy L. Fletcher in May 2012
Life International (1963) DNA's code: key to all life. Life Int 35(9):38–43
Lloyd C (2010) Leave the extinctions to Mother Nature, not the Red List. The Telegraph 29 September. http://www.telegraph.co.uk/earth/wildlife/8032917/Leave-the-extinctions-to-Mother-Nature-not-the-Red-List.html. Accessed 2 September 2014
McGregor A (2004) Sustainable development and warm fuzzy feelings: discourse and nature within Australian environmental imaginaries. Geoforum 25:593–606
Mitchell WJT (2003) The work of art in the age of biocybernetic reproduction. Modernism/Modernity 10(3):481–500
Mitman G (1996) When nature is the zoo: vision and power in the art and science of natural history. Osiris 11:117–143
National Audubon Society (2014) About the Christmas bird count. http://birds.audubon.org/about-christmas-bird-count. Accessed 2 September 2014
National General Medical Sciences (2010) Glossary: the new genetics. Bethesda. http://publications.nigms.nih.gov/thenewgenetics/glossary.html. Accessed 6 May 2014
National Human Genome Research Institute (2014) DNA sequencing costs. Bethesda. http://www.genome.gov/sequencingcosts/. Accessed 17 April 2014
Nelkin D (2001) Molecular metaphors: the gene in popular discourse. Nat Rev Genet 2:555–559
Nobelprize.org (2014) http://www.nobelprize.org/nobel_prizes/medicine/laureates/1962/. Accessed 2 September 2014
Roberts D (2011) Fatal invention: how science, politics and big business re-create race in the twenty-first century. The New Press, New York
Rose N (2001) The politics of life itself. Theory Cult Soc 18:1–30
Rose N (2007) Molecular biopolitics, somatic ethics, and the spirit of biocapital. Soc Theor Health 5:3–29
Royal Ontario Museum (2009) Canadian Barcode of Life initiative. http://www.rom.on.ca/en/collections-research/research/natural-history/canadian-barcode-life-initiative. Accessed 7 May 2014
Rubinoff D (2006) DNA barcoding evolves into the familiar. Conserv Biol 20(5):1548–1549
Schermer M (2009) They could have used a robot: technology, nature, experience and human flourishing. In: Drenthen MA, Keulartz FWJ, Proctor J (eds) New visions of nature: complexity and authenticity. Springer Science and Business Media, Dordrecht, pp 41–46
Schrodinger E (1944) What is life. http://whatislife.stanford.edu/LoCo_files/What-is-Life.pdf. Accessed 20 April 2014
Schulman AN (2011) GPS and the end of the road. The New Atlantis Spring:4–32. http://www.thenewatlantis.com/publications/gps-and-the-end-of-the-road. Accessed 11 May 2014
Schulz K (2010) Interview with Amy L. Fletcher, Smithsonian Institute, National Museum of Natural History, Washington, D.C., 22 January 2010
Steinke D (2013) Ten years of DNA barcoding. Barcode Bull 4(2):2–3. http://ibol.org/wp-content/uploads/2013/12/iBOL-Barcode-Bulletin-Dec-2013.pdf. Accessed 7 May 2014
Wade N (2004) A species in second. The New York Times. 14 Dec. http://www.nytimes.com/2004/12/14/science/14barcode.html?_r=0. Accessed 20 April 2014
Waldby C (2002) Stem cells, tissue cultures and the production of biovalue. Health 6(3):305–323

Weight L (2010) Interview with Amy L. Fletcher, Smithsonian Institute, National Museum of Natural History, Washington, D.C., 22 January 2010
Wente M (2008) Canada's marvelous library of life. The globe and mail, 13 Dec: A25
Wilson EO (2003) The encyclopedia of life. Trends Ecol Evol 18(2):77–80
Wilson EO (2004) Taxonomy as a fundamental discipline. Phil Trans R Soc Lond Soc. B 359(1444):739
Wilson EO (2007) My wish: build the encyclopedia of life. Speech delivered at TED2007, Vancouver, March. http://www.ted.com/talks/e_o_wilson_on_saving_life_on_earth. Accessed 6 May 2014
Witcher T (2010) Update on the Smokies all-taxa biodiversity inventory. Presentation at Wilderness Wildlife Week, Pigeon Forge, 3 Feb
Young P (1991) The library of life. The Sunday mail, 24 March

Chapter 4
Bio-Interventions: Cloning Endangered Species as Wildlife Conservation

Abstract This chapter analyses the debate about reproductive cloning of endangered species. Humans first domesticated chickens, cattle and sheep in order to produce reliable food sources. Efforts to improve livestock led to the science of animal husbandry and eventually to the large-scale factory farms characteristic of modern societies. The technologies that enable reproductive cloning of endangered species have their roots in the imperative to improve the productivity of farm animals, making their use for environmental reasons controversial within the broad field of conservation. Allies in the war against extinction often find themselves at odds over whether or not cloning should be incorporated into the conservation genetics toolbox. Opponents raise concerns both about the diversion of scarce resources from habitat preservation and the vexed question of which species should be chosen as candidates for such high-tech interventions. Advocates counter that any tool that can stave off the rapid disappearance of genetic diversity is essential to consider and ethically justified. In order to address these arguments, this chapter begins with an historical account of the simultaneous emergence of the animal welfare movement and modern biotechnology in the late 19th century. It then turns to a discussion of mid-20th century advances in biotechnology, particularly with respect to cloned and transgenic animals. The chapter concludes by analyzing advances in endangered species cloning since the birth in 2001 of Noah, a baby gaur and the first endangered species to be cloned via somatic-cell nuclear transfer. The conclusion of the chapter focuses on the social and ethical implications of preservation in a petri dish.

> *The central task of science is to arrive, stage by stage, at a clearer comprehension of nature, but this does not at all mean, as it is sometimes claimed to mean, a search for mastery over nature.*
>
> —Lewis Thomas (1983)

4.1 Is Nature Over?

In March 2012, Time magazine listed "Nature is over" as idea #9 in a cover story on "10 Ideas that are Changing Your Life". This assertion drew upon and popularized approximately thirty years of scholarly analysis in such disparate fields as public policy, environmental science, sociology and anthropology. The premise is straightforward. In the so-called Anthropocene, "there may simply be no room for nature, at

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least not nature as we've known and celebrated it—something separate from human beings—something pristine. There's no getting back to the Garden, assuming it ever existed" (Walsh 2012, p. 85).

The idea of cloning endangered species as a response to the extinction crisis is controversial precisely because it suggests that nature as we've known it may, in fact, be over. Of course, advocates of the reproductive cloning of endangered species might note that the human imprint on nature began at least 10,000 years ago when we domesticated chickens, cattle and sheep to produce reliable food sources and first slaughtered woolly mammoths and other palaeolithic beasts with lethal Clovis spear points. Efforts to improve domesticated species led to the science of animal husbandry and eventually to the large-scale factory farms characteristic of modern industrial societies. Human manipulation of animals at the genetic level is not new, but it has become much more sophisticated at the dawn of the twenty-first century. For example, in an article titled "The Perfect Milk Machine: How Big Data Transformed the Dairy Industry", Alexis Madrigal notes that "in 1942, when my father was born, the average dairy cow produced less than 5,000 pounds of milk in its lifetime. Now, the average cow produces over 21,000 pounds of milk" (Madrigal 2012). Because the issue of reproductive cloning of endangered species has its scientific roots in the imperative to improve the productivity of farm animals, and thus in a worldview that treats animals, however humanely, as a production unit subject to improvements and upgrades, cloning as an urgent response to the biodiversity crisis remains intensely controversial. Allies in the war against extinction find themselves at odds over whether or not cloning should be incorporated into the conservation genetics tool-box. Opponents raise concerns about the diversion of scarce conservation dollars to expensive and uncertain cloning methods, as well the vexed question of which species should be chosen as candidates for such high-tech interventions. Advocates counter that given the scale of the extinction crisis, any tool that can stave off the disappearance of genetic diversity is essential to use and ethically justified. Indeed, for some prominent advocates, an ethical stance demands the use of cloning and other biotechnological interventions with endangered species. As Robert Lanza, Chief Scientific Officer at Advanced Cell Technologies and Adjunct Professor at Wake Forest University School of Medicine, argues " 'a hundred species are lost every day and these mass extinctions are our own doing. Now we have the technology to reverse that, I think we have the responsibility to try' " (Nash 2001).

The following chapter analyses the debate about reproductive cloning of endangered species, focusing on the fundamental question of whether or not preservation in a petri dish serves the cause of wildlife preservation. It begins with an historical account of the parallel rise of the animal welfare movement and a modern biotechnological industry that depended upon standardized laboratory animals as experimental specimens. It then discusses the development of transgenic animals in the 1990s, focusing on the arrival of Dolly the Sheep in 1997 and significant scientific breakthroughs in genetically modified animals that followed. The third section addresses the question of animal commodification and the controversial idea that genetic resources and genetically modified animals are sources of biovalue that necessitate intellectual property protection of what had previously been considered, simply, life.

The fourth section analyses advances in endangered species cloning since the birth in 2001 of Noah, a baby gaur that provided proof of concept that cross-species reproductive cloning of an endangered species was feasible in certain cases. The conclusion focuses on the potential consequences of reproductive cloning for our ideas about nature and wilderness. If opponents are correct, then cloning endangered species is, at best, an expensive and short-term response to the extinction crisis that cannot alter the overall trajectory of loss. On the other hand, the advocates make a compelling argument when they note that reproductive cloning, however imperfect a solution, may represent our last, best chance of providing future generations with a world that includes tigers, pandas, cheetahs, tamarins, elephants, gorillas, black rhinos, giant tortoises, great white sharks, blue whales, green turtles. . . . The list goes on.

4.2 The Molecular Frontier: Biotechnology and Life as Code

Animal welfare and animal manipulation are closely intertwined throughout late nineteenth century politics and science though, as with most things Western, philosophical interest in the moral status of animals dates to the ancient Greeks. The Pythagoreans, for example, counselled respect for animals because they believed in the transmigration of souls between human and animals bodies. The Stoics, conversely, regarded as animals as slaves, without moral status (Wise 2006). For our purposes, it is important to turn briefly to the animal welfare movements of the nineteenth century, which paralleled and reacted to such social forces as progressivism, women's rights, and the rise of modern medicine and science in the United States and Western Europe.

The contemporary animal welfare movement began in Victorian England. The Royal Society for the Prevention of Cruelty to Animals (RSPCA) was established in 1824, followed by the American Society for the Prevention of Cruelty to Animals in 1866. The world's first *Cruelty to Animals Act*, passed by the British Parliament in 1835, was a significant victory for the RSPCA, as it extended previous regulations requiring the humane treatment of cattle to include dogs and sheep and introduced new prohibitions on bear-baiting and cockfighting. The practice of animal vivisection, which most scientists and medical professionals then considered crucial to development of modern medicine, particularly excised animal welfare advocates. For example, Caroline Earle White (1833–1916), a philanthropist and anti-vivisection activist, co-founded the Pennsylvania Society for the Prevention of Cruelty to Animals in 1867 and participated in the formation of the American Anti-Vivisection Society (AAVS) in 1883. Her belief that "when it comes to the last hour of your life, it will be a great consolation to feel that you always protected the poor, the helpless, and the unfortunate; and that you exercised a particular care towards animals (AAVS 2014)" embodies the unique combination of paternalism and progressivism that underwrote the animal welfare movement. This era, in turn, laid the groundwork for the more radical animal rights and animal liberation movements that arose in the late twentieth century.

At the exact historical moment that animal welfare becomes a salient political issue in most Western countries, the enduring idea that animals are machines, originally credited to René Descartes (1596–1650), took a new turn with rapid advances in biotechnology and medicine. Gregor Mendel's (1822–1884) famous experiments with pea plants, conducted in his monk's garden at the Abby of St. Thomas in the Czech Republic, first established a mathematical pattern to the inheritance of traits. The notebooks that painstakingly documented his findings lay dormant and unheralded until approximately 1900, when Hugo de Vries, Carl Correns and Erich von Tschermak-Seysenegg rediscovered them. William Bateson, who later coined the term genetics, translated Mendel's work into English and helped establish the Cambridge School of Genetics by 1908. The initial synthesis of Mendel's insights with Darwin's theory of evolution by natural adaptation provided the necessary foundation for a science of molecular biology that would flourish by the mid twentieth century. At the 1901 World Zoological Congress, Gustav Tournier proposed the idea of *bionten*, meaning the study of technology as applied to living organisms, and also proposed the term *biontotechnik* to refer to the prospect of genetic modification. Anticipating the type of public reactions that would later characterize the discovery of the DNA double helix in the 1950s and the birth of Dolly the Sheep in 1997, Bateson, for his part, believed that "an exact determination of the laws of heredity will probably work more change in man's outlook on the world, and in his power over nature, than any other advance in knowledge that can be foreseen" (Henig 2000, p. 3).

This new research into genetics and heredity required a reliable supply of animal specimens. Hermann von Helmholtz (1821–1894), a German physician, physicist and polymath, had by the 1840s already commemorated frogs as the "old martyrs of science", so often were they the subjects of laboratory experiments. By the end of the nineteenth century, several species of mammals also became crucial tools in the life sciences and medical research. By the start of World War I in 1914, lab animals were a standard commercial product (before 1890, they had not been bred for experimental purposes). Just as the new demands of large-scale farming required innovative techniques of selective breeding, the industrialization of animal production was a commercial response to medicine's significant shift to the experimental model and its attendant need for research on living bodies. The Wistar Rats are perhaps the most famous of the standardized animals from this era and were sold to laboratories until the 1960s. Bonnie Clause (1993) notes that "purposeful and systematic intervention was required to mould these feral animals, unreliable and unpredictable, into biological entities that could be counted on to consistently and invariably yield a productive day's work" (p. 30). Milton Greenman, Director of the Wistar Institute in Philadelphia, and Helen Dean King, the scientist who led most of the breeding work, realized by 1906 that the new laboratories of modern medicine would require reliable supplies of experimental subjects in essentially the same way that the nascent automobile industry would depend upon standardized parts and the regularization of the workforce. Milton Greenman recognized that the rat could be "a living analog to the pure chemicals that legitimated experimental science" (Clause 1993). Consequently, several decades before the intellectual property wars instigated by the legal case of

Diamond v. Chakrabarty (1980), in which a scientist sought patent protection for a genetically engineered microorganism, the Institute took unprecedented steps to protect its proprietary rights in the Wistar Rat.

The study of genetics became highly politicized by the 1920s, taking a dangerous detour into eugenics. Sir Francis Galton defined eugenics as "the science which deals with all of the influences that improve the inborn qualities of a race; also with those that develop them to the utmost advantage" (1904). Galton recognized that nature and nurture work together in shaping the individual, but the majority of eugenics-oriented work in both science and public policy focused on improving the so-called "human genetic stock" of a nation via attempts to direct inheritance and procreation. The mechanisms used to regulate human reproduction could range from rewarding the "fittest" children at "better baby" contests (positive eugenics) that proliferated throughout the United States in the 1920s and 1930s to punitive measures such as forced sterilization (negative eugenics). Countries including the United States, France, Iceland, South Africa and Australia had academic eugenic societies and public policies during the Progressive Era. Ultimately, the distorted and racist application of eugenic ideas contributed to the catastrophe of the Nazi Period and the Holocaust. Indeed, the severity of the human rights abuses committed by the Nazi regime in the name of medicine and the Nation during the 1930s and 1940s resulted in a brief period in the immediate post World War II era wherein genetic research, even at prestigious institutions such as Cambridge University, had to be conducted relatively discreetly due to intensely negative public opinion about the subject (Munk-Jorgersen and Ewald 2001; Porter 2001).

Nevertheless, significant public and private research in molecular biology continued in both Britain and the United States, culminating by mid-century in the elucidation of the molecular structure of DNA, the so-called molecule of life. James Watson and Francis Crick published their groundbreaking paper on the DNA double helix in *Nature*, in April 1953. The 1962 Nobel Prize in physiology or medicine was awarded jointly to James Watson, Francis Crick and Maurice Wilkins for their discoveries about the molecular structure of nucleic acids and the significance of the double helix model for information transfer in living material. At this point, due to both the publicity surrounding the Nobel Prize and the intense American emphasis on large-scale scientific research that followed the 1957 Soviet launch of the Sputnik satellite, DNA research became highly visible in the mainstream media. *Life International*, for example, published a glossy front-page colour image of the double helix for a 1963 issue that showcased the potential implications of genetic research for such issues as illness and aging. It referred to a "new country" called molecular biology and, echoing William Bateson, asserted that this new world "promises to yield unprecedented power for man—power to manipulate nature in ways that he cannot now even imagine" (Hills and Rosenfeld 1963, p. 45). Even without a date or issue number, the article could probably be reliably tracked to the early 1960s, as it abounds with references to molecular biology as a new frontier awaiting exploration (echoing President John F. Kennedy's speeches on space) and assertions that the power of the DNA molecule would exceed that of the atom, the preeminent scientific obsession of the Cold War, once man had unlocked its myriad of secrets.

Perhaps most significantly, the issue introduces a mainstream audience to the idea that "DNA is the keeper of the code for all life everywhere" (*Life International* 1963, p. 40). Katrin Weigmann (2004), in an analysis of public understanding of scientific metaphors, notes that "from today's perspective it seems rather inevitable that, when people started to think about the molecular basis of inheritance, they came up with these [digital] analogies". As discussed in the previous chapter, Erwin Schrodinger's "What is Life" speech before the Dublin Institute for Advanced Studies at Trinity College, in February 1943, already contained references to a "code script" that determined "whether the egg would develop, under suitable conditions, into a black cock or a speckled hen, into a fly or a maize plant, a rhododendron, a beetle, a mouse or a woman" (Schrodinger 1944). By the 1950s, physicists, cyberneticists and mathematicians had all infiltrated the field of molecular biology, bringing with them an emphasis on quantification, computerization and the search for law-like regularities in the biological world. The contemporary elision of living things with information processing systems "can be traced to twentieth-century physicists' perplexity over how to account for self-organization in life given the second law of thermodynamics, entropy" (Turner 2002, p. 887). Conceptualizing DNA as an information code addressed that dilemma and also reinvigorated the idea of animals as living systems that could be changed or perhaps even rewritten via biotechnological interventions.

4.3 From Wistar Rats to Oncomice: Engineering Animals

In term of mainstream public awareness, the next major leap forward in genetic engineering occurred in 1972, when Paul Berg created the first DNA molecule that combined genes from different organisms. His initial experiments spliced the DNA of the lambda virus into the DNA of simian virus SV40, resulting in the first man-made recombinant DNA (rDNA). This work, for which Berg received a Nobel Prize in Chemistry in 1980 (shared with Walter Gilbert and Fredrick Sanger), demonstrated that genetic material from one organism can be artificially introduced into the genome of another organism and then replicated and expressed by that other organism (Chemical Heritage Foundation 2010). Herbert Boyer and Stanley Cohen built upon Berg's findings to create the first rDNA organism in 1973. These innovations subsequently gained the attention not only of the pharmaceutical and food industries, but also the U.S. Government and the general public. At the time, the fear that a laboratory gene-splicing experiment could unleash a virulent new virus into the population and the environment animated public unease with the new reality of genetic engineering, as did concerns that mankind in its hubris had begun to tamper with the essential foundation of life and biodiversity. The scientific community, led by Paul Berg, responded to these concerns with the Asilomar International Conference on Recombinant DNA Molecules in February 1975, wherein 140 scientists met to discuss the regulation of recombinant DNA and to consider the proper ethical relationship between biotechnology, science and society. A consensus emerged that

self-regulation within the scientific community combined with governmental oversight would be institutionally robust enough to protect society from the potential risks of rDNA, while maximizing its public health and economic potential.

The so-called "Asilomar consensus" remains a touchstone in debates about biotechnology governance and regulation. Stitch (1978), for example, argues that the Asilomar debate about rDNA and its potential consequences outside the laboratory represented a positive new turn in science-society relations, since it was the first time that modern science had emerged from the lab to participate in a visible public discussion of the risks and benefits of a new line of research. Tucker and Zilinskas (2006) likewise conclude that the Asilomar model "has since proven remarkably successful [and] bears emulating today" (p. 44, 45). Yet for the non-governmental and activist groups that began to enter the scientific arena in the 1970s, the Asilomar consensus did not reflect a new spirit of transparency, but instead a stage-managed effort to contain the new political dimension of research in molecular biology within an expert-driven and elite circle of interests. For example, GeneWatch (2006) more recently responded to Asilomar-like efforts by the synthetic biology community essentially to regulate itself by arguing that "the effect of the Asilomar declaration was to delay the development of appropriate government regulation and to forestall discussion on how to address the wider socio-economic impacts" of biotechnological innovation.

The Asilomar declaration, based on self-policing by ethical professionals and a cooperative relationship with national regulatory authorities, remained the dominant mode of bio-scientific governance in the United States and Western Europe until the 1980s, when the precautionary approach, which puts the regulatory burden-of-proof about safety on advocates of a new technology, emerged to challenge it. By the 1980s, highly-visible issues such as the Chernobyl nuclear reactor meltdown, the mad cow crisis in Britain, and acid rain had emerged to challenge the default position of professional self-regulation and collegial bureaucratic oversight. Advocates of the precautionary principle drew upon new theories of the risk society and post-normal science to argue that decisions on technological risks are explicitly political because they reflect value judgments and competing qualitative assessments of both uncertainty and the level of risk society should be expected to bear. So-called normal science, with its emphasis on quantitative risk assessment and expert-driven consensus, arguably could not incorporate the societal dimension of risk, while issues such as the safety of nuclear power plants and toxic waste demonstrated that there is "little or no politically neutral ground" on which to negotiate or reach public closure on different perceptions of technological and scientific uncertainties (Pellizzoni 2005, p. 594). Extending from this insight, the loose coalition of scholars and practitioners now working within the fields of post-normal risk assessment and public communication of science urge increased stakeholder involvement in decision-making, attention to the disparate values that often underlie arguments about evidence, and the incorporation of civil society into debates about scientific and technological futures.

This brief history of rDNA regulation matters to this discussion of endangered species cloning because biotechnological innovations today emerge in a

post-Asilomar environment often characterized by intense and organized political opposition to the biotechnology industry and to further technoscientific manipulation of natural processes. The Asilomar model of light regulation and reliance on scientific norms of good conduct may remain the norm in the United States. However, the uncertainties and social tensions reflected in the advance of the precautionary approach cannot be simply wished away by advocates of new and disruptive technologies. As Andrew McGregor (2004) argues, in opening nature to public attention specialists have relinquished authority over the constitution and meaning of nature and allowed nature to be contested by a much wider variety of "stakeholders" (p. 594). There is no turning back the clock to a time when debates about major advances in biotechnology could be contained within the laboratory and scientists could expect to receive largely sympathetic media coverage when they debut their findings on the public stage. The fierce opposition to genetically-modified food and transgenic animals that often erupts in the political arena suggests that advocates of cloning for conservation cannot simply assume that the scale of the extinction crisis corresponds to a general endorsement of their techno-scientific agenda. Disputes about endangered species cloning, though often couched in the language of science and public policy, reflect much more intangible worldviews about the proper relationship between science and nature, the intrinsic value of wild animals, and the meaning of concepts such as "wilderness" and "nature".

By the 1980s, the emerging opposition to transgenic animals found a potent symbol in the Oncomouse (registered trademark), a mouse genetically engineered to carry a specific gene (called an oncogene) that made it significantly more susceptible to cancer than regular mice. The Oncomouse, the result of a partnership between researchers at Harvard College and financial backers at the DuPont corporation, took the idea of the Wistar Rat into the Age of Biotechnology. The point of creating it was to provide research labs with a standardized experimental subject that could be used for various forms of cancer research. Public aversion to the Oncomouse stemmed not only from the transgenic manipulation of a mammal, which many observers likened to "playing God", but also from the suffering inherent in the cancer that was all but inevitable for these animals. However, it was Harvard's decision to seek patent protection for the Oncomouse that ignited the fiercest opposition and inspired an unusual coalition of the National Council of Churches, farming interests, and animal rights activists to protest in the United States via demonstrations and letter-writing campaigns (Gerlach et al. 2011). The Supreme Court of the United States had already ruled in *Diamond v. Chakrabarty* (1980) that lower life forms, such as engineered microorganisms, could be patented. However, the decision by the United States Patent and Trade Office to grant patent no. 4,736,866 to Harvard in 1988 seemed to many both unwise and unprecedented, particularly since the patent protection extended not only to the process by which the Oncomouse was made but also to the end product, the animal, itself.

Following a similarly fraught and protracted debate, the European Patent Office concluded in 1992 that the medical benefits of the Oncomouse outweighed both the public morality exemption in European patent law and concerns about animal suffering. It granted Harvard a patent, though it did limit the protection to claims

about mice. Interestingly, the Canadian Supreme Court split 5–4 in its initial decision not to recognize the patent, arguing that the moral and political questions raised by the Oncomouse were more appropriately handled by Parliament than by the courts. Advocates for the Canadian biotechnology industry criticized the Court's decision as scientifically retrograde and potentially damaging to Canada's global competitiveness. Ultimately, in 2003, Canada did grant a patent to Harvard College for the process by which the oncomice were created, though not for the actual mice. Despite the intricacies of international patent law, by the mid 1990s a global precedent for patents on methods such as mammalian cloning and (in some countries) patents on the animal that resulted) had been established.

4.4 Dolly and Polly: Animal Cloning Hits the Big Time

Following the Canadian Supreme Court's original decision to deny the Oncomouse patent, Jerry DeMarco, a lawyer for Sierra Legal Defense Fund, stated that "The Supreme Court's judgment recognizes that animals aren't 'invented' like airplane engines and toaster ovens. They are living beings whose intrinsic value must be respected" (MacCharles 2002). Yet advances in genetic engineering continued to challenge this fundamental premise, as the processes by which molecular biologists could manipulate animal genetics became ever more precise and powerful. Dolly the Sheep's arrival on the world stage in January 1997 received the intense media attention that it did because she took us decisively into the world of somatic-cell nuclear transfer (SCNT) reproductive cloning of mammals, which had previously been declared biologically impossible by many in the scientific community. Dolly, also known as sheep 6LL3, embodied the crossing of a biological boundary that had previously seemed sacrosanct. In creating Dolly, Ian Wilmut and his team at the Roslin Institute had, in United States Senator Ted Kennedy's words, " 'broken the biological equivalent of the sound barrier' " (Vedantam 1997).

Experimental research on cloning began in the late 19th century. German biologist Hans Driesch was the first known scientist successfully to use embryo twinning, in 1891. He took a two-celled sea urchin embryo, shook it apart, and found that each cell developed into a complete individual. SCNT research, which dates to the 1920s and the work of Hans Spemann (a German embryologist who won a Nobel Prize in 1935 for his discovery of embryonic induction), refers to a laboratory procedure in which the nucleus of a somatic (body) cell from a donor animal is transferred to the cytoplasm of an enucleated egg and implanted in a surrogate animal. Dolly (1996–2003) was the first mammal to be cloned from an adult somatic cell, in her case a cell from the mammary gland of an ewe. As scientifically significant as this breakthrough was, Dolly's birth resonated even more profoundly with the cultural perception that we were on the precipice of a new era of biotechnological supremacy in which all of Nature was potentially subject to technological manipulation. The sheep, perhaps the most reassuring of domesticated species, one which appeared in

nursery rhymes and bedtime stories, suddenly became the symbol of a new post-natural age. Dolly occasioned scores of academic articles and books such as *Dolly Mixtures: The Remaking of Geneology* (Franklin 2007) and *Clone: The Road to Dolly and the Path Ahead* (Kolata 1998). The creation of Dolly also provided new impetus to the life as code metaphor, given that she confirmed that adult cells could be "reprogrammed" to revert to primitive cells "capable of generating new tissues, organs and even entire animals" (Boyd 1998). For Ian Wilmut, perhaps the most important thing about Dolly was that she " 'made people think very differently about biology. [She] is one of the things that made people much more ambitious and optimistic' " about such possibilities as experiments with stem cells (Kolata 2003).

Dolly was soon followed by Polly, the first mammal produced by SCNT cloning that also carried a human gene transferred through recombinant DNA techniques. The transgenic Polly resulted from a collaboration between the Roslin Institute and PPL Therapeutics and expressed a human protein in her milk (blood-clotting factor IX) that made it suitable for consumption by haemophiliacs and bone disease sufferers. Polly did not receive nearly the same amount of media coverage as Dolly, who had prompted President Bill Clinton to call for a 5-year moratorium on human cloning research so that society could catch-up to the ethical and political implications of advanced reproductive biotechnologies. Polly's birth, however, is arguably the more significant event in that she is a proof-of-concept that biopharming—the production of human medicines through genetically modified livestock—is feasible. As Alan Colman, PPL's research director, argued " 'this is a realization of our vision to produce instant flocks or herds which express high concentrations of valuable therapeutic proteins very quickly' ", (CNN.com 1997). Though animal cloning has recently been pulled into debates about how best to address the extinction crisis, the main impetus for animal cloning research derives from the goal of increasing the production capacity of livestock and thus creating value-added foodstuffs to market globally for higher profit margins than traditional meat or milk. In turn, appeals for financial support of government-sponsored cloning research are usually based on the potential human health applications that could result. For example, a symposium in Australia titled "Death and Resurrection: The Science of Living, Dying and Reversing Extinction" ultimately emphasized the importance of animal cloning research to the global competitiveness of the Australian dairy industry. It also stressed that "research into animal cloning is providing basic information on cell biology—information that helps us understand just what makes cells tick. This understanding is crucial for finding answers to disease such as cancer that afflict animals and people alike" (UTS Research 2003).

By 1999, the first male clone created from adult cells, a mouse named Fibro, had been produced at the University of Hawaii, the result of 274 experimental attempts (Abdulla 1999). Fibro was significant both because of his sex and because the cells that produced him were not taken from the reproductive system, as was the case with previous cloned mammals. (Fetal cells are generally much easier to clone because of their early stage of development). Fibro, who came from the cells of an adult mouse, suggested that it was possible to clone animals from a tail snip or other body sample rather than having to work from frozen embryos. The researchers claimed that Fibro

demonstrated that "precious animals of either sex, for example endangered species and transgenic animals, can be propagated by cloning irrespective of their fertility status" (ABC News 1999). At the start of the twenty-first century, animal cloning now seemed poised to revolutionize not only agriculture and health, but also conservation. That cloning research, which began with agriculture and moved to human health, could find a third application in saving endangered species is for its advocates the whole point of technological innovation and human ingenuity. Yet opponents often counter that the new emphasis on endangered species is ultimately a marketing ploy, used to ensure public enthusiasm for ongoing financial support of a research agenda that is primarily about corporate profits and private financial gain.

4.5 Noah's Ark: Cloning on the Edge of Extinction

Noah the gaur was born on 8 January 2001 at Trans-Ova Genetics in Sioux City, Iowa, a cattle genetics company hired by Advanced Cell Technology, which had paid for and conducted the research. Noah was the first endangered species to be born via SCNT, the product of fusing the cells of a rare wild ox with the enucleated egg of a domestic cow. The experiment began with the sampling of 692 skin fibroblasts taken from a dead gaur. Of these, 81 samples fused with the cow eggs to become embryos, 44 of which were implanted in cow surrogate mothers. Noah was the only fetus successfully brought to term, though he died within 48 h of birth due to dysentery. ACT spokesperson Robert Lanza noted that dysentery was common among newborn gaurs (and hence likely unrelated to the method by which Noah was produced) and stated that " 'despite this setback, the birth of Noah is grounds for hope. We still have a long way to go, but as this new technology evolves, it has the potential to save dozens of endangered species' " (Wired.com 2001).

Like Dolly, Noah achieved worldwide fame, in his case as the symbol of a new, high-tech approach to the extinction crisis. The theme of hope reverberated throughout media coverage and scientific discussion of Noah, a significant change from the rhetoric of crisis that had dominated environmental reporting since the late 1960s. For example, Dr. Kurt Benirschke, former president of the Zoological Society of San Diego, noted that though " 'The Zoological Society is saddened by the news of Noah's death... we are encouraged that scientists are learning to perfect this process and have continued hope for its inevitable role in the conservation of endangered species' " (AgBiotechNet 2001). Newspaper headlines such as "How Noah the Clone Could Bring Dying Breeds Flooding Back" (The Express), "Resurrection Hope for Rare Species" (The Birmingham Post), "Ox Clone could Lead to End of Extinction" (The London Times) and "Cloning: Science that Might Have Saved the Dodo: Helping the Doomed" (The National Post), promoted the idea that science had found a cure for extinction. Several newspapers referred to Jurassic Park, the fictitious theme park of resurrected dinosaurs so colourfully portrayed in both Michael Crichton's novel (1990) and the popular film (based on the novel) released by Amblin' Entertainment in 1993. For example, *The Sunday Telegraph*, in a report made prior to Noah's

birth, contended that "if successful, scientists will have accomplished the world's first resurrection of an extinct species, bringing the dinosaur theme park fantasy in Steven Spielberg's Jurassic Park a step nearer to theoretical reality" (Marsh 2000). Of course, theoretical reality is a misnomer and dinosaur fossils (as discussed in chap. 5) are so ancient as to remain forever beyond the reach of somatic-cell nuclear cloning.

Not everyone was as impressed with either Noah as ACT was. Critical commentary often noted that the gaur is classified by the International Union for the Conservation of Nature (IUCN) as vulnerable (high risk of extinction in the wild), rather than endangered (very high risk of extinction) or critically endangered (extremely high risk of extinction in the wild). The gaur population in India numbers approximately 36,000 animals, well above the numerical threshold for critically endangered status (less than 250 mature individuals remaining). When compared to mammalian species such as the amur leopard (less than 400 remaining in the wild) and mountain gorilla (less than 900 remaining in the wild), and particularly when compared to the plight of the less glamorous amphibians (of which one third or more of the approximately 6,300 known species are at risk of extinction), a cloned gaur seemed to many observers less of a radical breakthrough for conservation than a post-Dolly parlour trick. The Center for Ethics and Toxics, an activist organization then based in California, was among many critics who raised the issue of Noah's real purpose, predicting that "by the time Noah steps out of the flashbulbs, ACT acknowledges he will never end up in the wild. In fact, in spite of the public relations effort to twist and pull on our heartfelt hopes of rescuing a dying species, ACT... acknowledged most of the cloned endangered animals will end up in zoos" (Bailey 2000).

Nevertheless, research on the cloning of endangered animals continued, propelled variously by the momentum of the Age of Biotechnology, the desire to enhance man's control over animal reproduction and the seeming intractability of the extinction crisis. In May 2001, researchers at the University of Teramo, Italy, in collaboration with the Roslin Institute, succeeded in cloning the mouflon, a critically endangered wild sheep native to the Mediterranean islands of Sardinia, Corsica and Cyprus. This cloned mammal survived infancy (indeed, the official announcement of its birth was not made to the media until it was 7 months old) and is a noteworthy scientific accomplishment because it represented the first time that an integrated package of reproductive biotechnologies was deployed to rescue an endangered species (Ptak et al. 2002). The mouflon also had cultural and social implications that are suggestive of the potential impact of cloning endangered species on a large scale. As Tracey Heatherington (2008) notes, "set against the background of ongoing tensions over the creation of a new national park in Sardinia, the story of the cloned mouflon signified the power of a new science to redefine the politics of biodiversity, undermining the cultural authority of shepherd towns over human-animal relations" (p. 9).

The Audubon Centre for Research on Endangered Species demonstrated in 2005 that cloned wildcats could breed naturally, producing a litter of healthy kittens. Director Dr. Betsy Dresser argued that, "by improving the cloning process and then encouraging cloned animals to breed and make babies, we can revive the genes of individuals who might not be reproductively viable otherwise, and we can save

genes from animals in the wild" (Audubon Nature Institute 2005). The success of such cloning experiments encouraged a parallel emphasis on the creation of so-called "frozen zoos", collections of tissues and cell cultures from endangered species preserved in liquid nitrogen at an approximate temperature of negative 200 degrees Celcius. The San Diego Zoo's Institute for Conservation Research (ICR) established the first frozen zoo in 1972. In light of Dolly, Polly, and then Noah, such collections, previously used for research and captive breeding purposes, now seemed both prescient and promissory. Oliver Ryder, a geneticist at the ICR, comparing each frozen species sample to a unique book, noted that though we " 'don't even know how to read these books right now... The information contained in any great library of books will have something of value to the future' " (Vedantam 1995). This emphasis on the future potential of frozen tissues and cells to reconstitute the endangered animal supports Carrie Friese's argument that "claims regarding the future use of cloning for species preservation create the grounds for its development in the present" (Friese 2013, p. 7).

4.6 Preservation in a Petri Dish

Despite the expense and the scientific uncertainties still inherent in mammalian cloning, large-scale attempts to clone endangered species are now relatively commonplace throughout the world. Since 2004, for example, projects have focused (to varying degrees of success) on animals such as the Asian lion (India), Giant panda (China), wild buffalo (India), coyotes (South Korea), and sei whales (Japan). Brazil's agricultural research agency (Embrapa), in consultation with the Brasilia Zoological Garden, launched a project in 2012 to pursue cloning of eight endangered species, including jaguars, maned wolves, black lion tamarins, bush dogs, collared anteaters, gray brocket deer and bison.

In *Nature's Experts: Science, Politics and the Environment,* Stephen Bocking (2004) argues that "the pervasive tendency in environmental politics has been to draw the line to favour science: to define problems so that they require scientific solutions, thereby converting political controversies into technical puzzles" (p. 201). The recent emphasis on endangered species cloning certainly prioritizes a particular type of technical knowledge over alternative approaches such as habitat preservation, exerting a significant influence both on how society may begin to perceive the extinction crisis and the epistemic communities who are most influential within conservation research and public policy. Anita Neville, spokeswoman for the World Wildlife Fund for Nature, captures the ambivalence about cloning in the conservation community when she argues (in response to a proposal to clone the giant panda in China) that these animals " 'are at risk because of poaching and poor habitat management. Cloning may give them a breathing space but if the causes of decline are not tackled, you won't end it' " (Hanlon and Smith 2000). Dr. Pan Wenshi, a leading expert on the Chinese panda, responded to the same proposal by emphasizing that pandas are disappearing because humans are destroying their habitats (O'Connell

2000). Indeed, the fear that glamorous, biotechnological interventions could begin to siphon scarce money and attention away from habitat preservation haunts the critical discourse about endangered species cloning. The potential moral hazard is that if the public starts to believe that biotechnology constitutes a reliable "end" to the extinction crisis, it will become much easier for us to ignore the imperative of habitat preservation and to give vested economic interests free reign to develop all the remaining wild regions of the planet. This fear is often expressed through the use of sarcasm. Allan Greer, in an editorial titled "Wildlife on Tap… just add DNA", writes in response to the idea of cloning endangered and even extinct species that thankfully there will be "no more need to waste vast tracks of habitat to conserve species. Tourists can advance order a few from Clone plc to be released in the appropriately landscaped enclosure at Wild Habitats plc; watch them for a while and then have the company 'recycle' them" (Greer 1999). Similarly, Graham Phillips in "No Clone Unturned" ironically exults that "putting bears on ice would be much easier than keeping them in zoos. There'd be no expensive enclosures or special dietary requirements to worry about: the world's entire wild panda population could be housed in a one-metre wide freezer" (Phillips 2000).

Metaphors such as "wildlife on tap", "genetic stockpiles", "test-tube tigers" and "snap frozen species" elide with the suspicion that a cloned species is somehow inauthentic or unnatural. One commentator, for example, asked "And what will become of Noah, born on an Iowa farm thousands of kilometres from its natural habitat, and with no members of its own species to keep it company" (Brook 2000)? The ambivalence expressed behind these words sounds remarkably similar to Alexis Madrigal's assessment, 12 years later, of the relationship between big data and dairy farming. Referring to a prized stud bull (Badger-Fluff Fanny Freddie), Madrigal writes that "he is, for all intents and purposes except for his own, genetic material that comes in the handy form of semen. His thousands of daughters will never smell him and his physical location doesn't matter to anyone. He will be replaced very soon by the next top bull, as subject to the pressures of our economic system as the last version of the iPhone" (Madrigal 2012). Nikolas Rose (2007), in an influential analysis of biotechnology, health and medicine, argues that life in the twenty-first century is increasingly understood and manipulated at the molecular level, in contrast to the focus on the body (what he refers to as the "molar" level) that characterized the nineteenth and twentieth centuries. This same process of molecularization now extends to the spheres of animal husbandry, wildlife management and conservation. It is both the de-materialization of the animal inherent in the idea of the frozen zoos and the inauthenticity of the cloned animal that seem most troublesome to critics.

In essence, the very "gaurness of the gaur" seems compromised as a result of a birth that takes place entirely within the confines of a laboratory. Yet the problem of what is "authentic" or "natural" is simultaneously deeply important to the debate about cloning endangered species and also a shaky platform upon which to mount opposition to cloning. Maartje Schermer (2009), in an article titled "They Could have Used a Robot", counters that "the mere fact that we create something does not necessarily make it an object to which we cannot relate authentically. We can create children, even in laboratories through IVF or ICSI, and still relate to them as human

subjects" (p. 43). Deplazes and Huppenbauer (2009), noting that new technologies such as synthetic biology all but erase the boundary between the synthetic and the living, argue that "living organisms traditionally exist, reproduce and change following natural rules, independently of the will of human beings. In contrast, in the artificial world human beings decide what exists, in what amount and in which form" (Deplazes and Huppenbauer 2009, p. 55). They develop a rubric for differentiating between machines and natural organisms that includes 4 criteria: composition, origin, development and purpose. Within this approach, the cloned animal is neither fully natural or inauthentic, but is instead a hybrid organism. It meets two criteria of the organism in that it each of its cells consists of organic material and it will develop, age and die. Yet, like the machine, the cloned animal arguably has a clearly defined and human origin. A cloned animal does not take us back to Descartes' moral equivalence between animals and machines, but it does take us further down the road of engineered animals and thus farther away from Muir's emphasis on the intrinsic value of the untouched world.

It is Deplazes and Huppenbauer's fourth criterion that raises the most interesting ethical conundrum with respect to the status of the cloned animal. With respect to purpose, they argue that a natural organism serves no external purpose and is driven by its own interests and natural development, while machines have been designed and written by human beings and exist to fulfil human needs. Roslin Institute scientist Keith Campbell's comment with respect to Dolly the Sheep that "obviously, I had thought about the ethics, but it was the biology that fascinated me" (Bowditch 2007) reflects an approach that prioritizes the scientific adventure inherent in cloning and turns the cloned animal into a proof-of-concept, a showroom's floor model of an innovative new product. Certainly, a cloned animal is still subject to the vagaries of life, to reproduction, eating, sleeping, accidents and disease. Yet one can reasonably ask, given that it exists only as a direct result of human intention, what is the real point of the cloned animal? If it is either a proof-of-concept or, as some observers contend, primarily "to entertain a steady stream of visitors to our zoos; [as] attention-getting creatures such as pandas and lions could bring in huge profits for entrepreneurs with private parks" (Dinerstein and Baragona 2000), then the ethical status of this research is suspect. Dale Jamieson, an animal rights expert, for example, refers in his book *Morality's Progress* (2002) to the "moral schizophrenia" of societies that romanticize the extinct animal while destroying habitats and confining a few extant, charismatic animals to enclosures.

Yet moral imperatives can cut both ways. It is possible to agree with conservationist William Conway when he argues that "even if we knew all that there is to know about the genetics of wildlife, we could not save a single species in nature unless we can influence the sovereignty of social and political forces" (Conway 2001) and still believe that it is better for animals to be artificially bred than dead. For proponents of endangered species cloning research, all of the objections may be worth debating, but these debates are taking place in the context of an extinction crisis that continues to accelerate mercilessly. Robert Lanza, for example, argues that " 'I am one of the biggest advocates of habitat preservation, but it doesn't do any good to protect the habitat if you don't have any animals left to protect' " (Lavendel 2001). Reproductive

cloning for wildlife preservation will affect what type of nature emerges in the twenty-first century and it will propel ongoing artificialisation—that is, "the vanishing of a fundamental boundary between natural and artificial, as a result of the use of modern technology" (Konsa 2008 p. 23) that has been occurring incrementally since the Pleistocene. Nevertheless, this chapter gives the last word, for now, to Dr. Betsy Dresser, previously of the Audubon Centre for Research of Endangered Species, who admits "it's not meant to save everything. But we're not going to stop advances in biotechnology. So let's use them to save what we can. Can you tell me in a hundred years what the future will be like? Will there be habitat? Perhaps yes, perhaps no. But at least we'll have tigers".

References

AAVS (2014) History of the anti-vivisection society. http://www.aavs.org/site/c.bkLTKfOSLhK6E/b.6452353/k.F40F/History_of_the_American_AntiVivisection_Society.htm. Accessed 14 May 2014

ABC News (1999) Males get cloned. http://abcnews.go.com/Technology/story?id=99183. Accessed 14 May 2014

Abdulla S (1999) First male clone. Nature, 3 June. http://www.nature.com/news/1999/990603/full/news990603-2.html. Accessed 14 May 2014

AgBiotechNet (2001) Cloned guar dies shortly after birth. AbBiotechNet. 17 May. http://www.cabi.org/agbiotechnet/news/261. Accessed 23 June 2014

Audubon Nature Institute (2005) Endangered African wildlife clones produce kittens. http://cats.about.com/od/cloningcats/a/audubonkittens.htm. Accessed 25 June 2014

Bailey B (2000) Cloning the gaur. Center for Ethics and Toxics. http://environmentalcommons.org/cetos/articles/cloninggaur.html. Accessed 24 June 2014

Bocking S (2004) Nature's experts: science, politics and the environment. Rutgers University Press, New Brunswick

Bowditch G (2007) Lasting legacy of the sheep that shook the world. The Sunday Times 21 January

Boyd RS (1998) Pieces to meeces: scientists in Hawaii clone three generations of mice. The Spokesman Review, 23 July:A2

Brook S (2000) The next beast thing. The Australian, 20 October: 15

Chemical Heritage Society (2010) Paul Berg, Herbert W. Boyer, and Stanley N. Cohen. http://www.chemheritage.org/discover/online-resources/chemistry-in-history/themes/pharmaceuticals/preserving-health-with-biotechnology/berg-boyer-cohen.aspx. Accessed 14 May 2014

Clause BT (1993) The Wistar rat as a right choice: establishing mammalian standards and the ideal of a standardized mammal. J Hist Biol 26(2):329–349

CNN.com (1997) Cloned sheep has human gene. CNN.com, 24 July. http://edition.cnn.com/TECH/9707/24/polly/. Accessed 14 May 2014

Connor S (2004) Frozen in time: British scientists to store DNA of endangered species for posterity. Belfast Telegraph, 27 July

Connor S (2010) The GM revolution in Britain's medical research laboratories. The Independent (London), 28 July:4

Conway W (2001) Extinction crisis and the loss of genetic diversity. Talk presented at the conference on conservation genetics in the age of genomics, American Museum of Natural History, 2001. http://www.amnh.org/our-research/center-for-biodiversity-conservation/events-exhibitions/conferences-and-symposia/2001-conservation-genetics. Accessed 25 June 2014

Deplazes A, Huppenbauer M (2009) Synthetic organisms and living machines: positioning the products of synthetic biology at the borderline between living and non-living matter. Syst Synth Biol 3(1–4):55–63

Dinerstein E, Baragona K (2000) A look at... protecting the wild. The Washington Post, 28 May:B03

Franklin S (2007) Dolly mixtures: the remaking of genealogy. Duke University Press, Durham

Friese C (2013) Cloning wild life: Zoos, Captivity and the Future of Endangered Animals. New York University Press, New York

Galton F (1904) Eugenics: its definition, scope, and aims. Am J Sociol 10(1). http://galton.org/essays/1900-1911/galton-1904-am-journ-soc-eugenics-scope-aims.htm. Accessed 20 April 2014

GeneWatch (2006) Text of an open letter from social movements and other civil society organizations to the synthetic biology 2.0 conference, 20–22 May, Berkeley, CA. http://www.genewatch.org/article.shtml?als%5Bcid%5D=507663&als%5Bitemid%5D=537746#OpenLetter. Accessed 14 May 2014

Gerlach N, Hamilton SN, Sullivan R, Walton PL (2011) Becoming biosubjects: bodies, systems, technologies. University of Toronto Press, Toronto

Globe and Mail (1987) The Globe and Mail (Canada), 30 April

Greer AE (1999) Wildlife on tap... just add DNA. The Australian, 19 May:12

Hanlon M, Smith D (2000) How Noah the clone could bring dying species flooding back. The Express, 9 October

Havlick D (2006) Reconsidering wilderness: prospective ethics for nature, technology and society. Ethics, Place and Environ 9(1):47–62

Heatherington T (2008) Cloning the wild mouflon. Anthropol Today 24(1):9–14

Henig R (2000) A monk and two peas: the story of Gregor Mendel and the discovery of genetics. Weidenfeld and Nicolson, London

Hills A, Rosenfeld A (1963) Nearer now! Control of aging and heredity. Life Int 35(9):45–50

Jamieson D (2002) Morality's progress. Oxford University Press, Oxford

Kolata G (1998) Clone: the road to Dolly and the path ahead. HarperCollins Publishers, New York

Kolata G (2003) First mammal clone dies: Dolly made science history. The New York Times, 15 February. http://www.nytimes.com/2003/02/15/science/15DOLL.html. Accessed 14 May 2014

Konsa K (2008) Artificialisation of culture: challenges to and from posthumanism. J Evol Technol 17(1):23–33

Lavendel B (2001) Can our cloned animals be brought back from the brink. Western Daily Press, 22 November:15

Life International (1963) DNA's code: key to all life. Life Int 35(9):38–43

MacCharles T (2002) Mouse patently not an 'invention.' Toronto Star, 6 December:A07

Madrigal A (2012) The perfect milk machine: How big data transformed the dairy industry. The Atlantic, 1 May. http://www.theatlantic.com/technology/archive/2012/05/the-perfect-milk-machine-how-big-data-transformed-the-dairy-industry/256423/. Accessed 25 April 2014

Marsh B (2000) Animals that hold the key to life. The Sunday Telegraph, 22 October:91

McGregor A (2004) Sustainable development and warm fuzzy feelings: discourse and nature within Australian environmental imaginaries. GeoForum 35:593–606

Monk-Jorgensen P, Ewald H (2001) Epidemiology in neurobiological research: exemplified by the influenza-schizophrenia theory. Br J Psychiatry Suppl 40:s30–s32

Nash S (2001) New tools, moon tigers, and the extinction crisis: biotechnology, genetics, and conservation biology are not always easy partners. BioScience 51(9):702–707

O'Connell S (2000) Black and white, not bred all over. The Guardian, 21 December:12

Ptak G, Clinton M et al (2002) Preservation of the wild European mouflon: the first example of genetic management using a complete program of reproductive biotechnologies. Biol Reprod 66(3):796–801

Paulson S, Gezon LL, Watts M (2003) Locating the political in political ecology: an introduction. Human Org 62(3):205–217

Pellizzoni L (2005) Trust, responsibility and environmental policy. Eur Soc 7:567–594
Phillips G (2000) Leaving no clone unturned. The Sunday Telegraph (Sydney, Australia), 29 October:43
Porter D (2001) Eugenics. Oxford Companion to the Body. http://www.answers.com/topic/eugenics. Accessed 20 April 2014
Rose N (2007) Molecular biopolitics, somatic ethics and the spirit of biocapital. Soc Theor Health 5:3–29
Schermer M (2009) They could have used a robot: technology, nature, experience and human flourishing. In: Drenthen M et al (eds) New visions of nature: complexity and authenticity. Springer Business Media, Dordrecht, pp. 41–46
Schrodinger E (1944) What is life. http://whatislife.stanford.edu/LoCo_files/What-is-Life.pdf. Accessed 14 May 2014
Stitch SP (1978) The recombinant DNA debate. Philos Public Aff 7(3):187–205
Thomas L (1983) Late night thoughts on listening to Mahler's ninth symphony. Viking Press, New York
Tucker JB, Zilinskas RA (2006) The promise and perils of synthetic biology. The New Atlantis Spring:25–45
Turner SS (2002) Jurassic park technology in the bioinformatics economy: how cloning narratives negotiate the telos of DNA. Am Lit 74(4):887–909
UTS Research (2003) Death and resurrection. http://cfsites1.uts.edu.au/research/news/detail.cfm?ItemId=7054. Accessed 24 June 2014
Vedantam S (1995) No, it's not Jurassic Park yet but. The Toronto Star, 17 December:F8
Vedantam S (1997) Dolly's cloner says think twice before legislating. The Inquirer, 13 March. http://articles.philly.com/1997-03-13/news/25572471_1_ian-wilmut-adult-sheep-nobel-laureate-and-director. Accessed 14 May 2014
Walsh B (2012) Nature is over. Time, 12 March. http://content.time.com/time/magazine/article/0,9171,2108014,00.html. Accessed 14 May 2014
Weigmann K (2004) The code, the text and the language of God. EMBO Rep 5(2):116–118
Wired.com (2001) Rare cloned ox dies. Wired.com. 12 January. http://archive.wired.com/science/discoveries/news/2001/01/41158. Accessed 23 June 2014
Wise SM (2006) Animal rights. Encylopaedia Britannica Advocacy for Animals, 4 December. http://advocacy.britannica.com/blog/advocacy/2006/12/animal-rights/. Accessed 20 April 2014

Chapter 5
Bio-Identities: Cloning the Recently Extinct

Abstract This chapter focuses on attempts to bring back recently extinct species with the use of advanced biotechnologies. The emerging discourse of de-extinction introduces significant opportunities and challenges for ecosystem management. In 1999, for example, the Australian Museum launched a research project premised as an attempt to determine whether or not the thylacine, an iconic Australian marsupial that disappeared in 1936, could be brought back via the use of advanced biotechnologies. Following quickly on the controversies sparked by Dolly the Sheep in 1997, the Thylacine Cloning Project (1999–2005) amplified concerns and hopes about animal cloning. Despite intense criticism of this early initiative, candidates proposed for de-extinction today include the passenger pigeon, Australia's gastric-brooding frog and even the Woolly Mammoth. To bring back an extinct species and establish it *in situ* on a sustainable basis would radically reshape human control over nature, though the feasibility and desirability of doing so remain controversial. This chapter begins with a cultural history of the field of ancient DNA analysis, before turning to an in-depth evaluation of scientific and public reaction to the thylacine cloning project. It concludes with a discussion of the fleeting but remarkable resurrection of the Pyrenean ibex in 2003 and the implications of the de-extinction agenda.

> *Death is only a state of black magic which did not exist so long ago.*
>
> —Antonin Artaud (Thacker 1999)

5.1 Liminal Lives: The Biopolitics of De-extinction

Nature's inventory has significant gaps caused by explicitly anthropogenic pressures such as war, habitat degradation, poaching and illegal trade in wildlife. Even a very short list of twentieth century extinctions includes the Yangtze River Dolphin, Atitlan Giant Grebe, Alaotra Grebe, Passenger Pigeon, Caribbean Monk Seal, Banks Island Wolf, California Golden Bear, Western Black Rhinoceros and the Bubal Hartebeest. However, recent progress in biotechnology now poses for some the tantalizing prospect that science may have found a way to restock the wilderness and retrieve what has been lost through human negligence or destruction. De-extinction, the controversial but powerful idea that molecular biology and genome sequencing will eventually enable scientists to bring back lost species, has in roughly 30 years gone

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from an idea disdained by most scientists to a prospect institutionalized through high-profile T.E.D. talks and projects such as Revive and Restore (an initiative affiliated with conservationist Stewart Brand's The Long Now Foundation). Haunting this new discourse of de-extinction are the numerous species destroyed by humans, all those spectral wraiths accessible to us now only through photographs, short silent film clips or scratchy audio recordings. To bring back an extinct species and establish it *in situ* on a sustainable basis would radically reshape human control over nature. The biopolitics of extinction, by which I mean, *pace* Michel Foucault, the way in which life and death have been brought into the realm of explicit calculation and manipulation, thus merits careful analysis not only of scientific claims and findings but also of the ethical and political dimensions of attempting to conquer extinction and thus defeat death.

In her book Liminal Lives: Imagining the Human at the Frontiers of Biomedicine, Susan Squier argues that our new ability to manipulate embryonic stem cells challenges "our fundamental sense that human life is unidirectional, proceeding ineluctably from conception to death" (2004, p. 2). The ability to extract viable fragments of ancient DNA from fossils, bones and other relics, I argue, also challenges our fundamental sense of time and death, upends the notion that extinction must be forever. Whether or not we will bring back an extinct species is an open question, but even the possibility that technoscience can now triumph over the finality of extinction is changing the discourse of environmentalism in important ways. This chapter analyzes the new de-extinction imaginary via an exploration of both the history of ancient DNA analysis and the public controversy surrounding the attempt to clone the Tasmanian tiger. The next section discusses the emergence of ancient DNA analysis and extraction in the mid 1980s, a development that ignited a fierce boundary dispute between those scientists who sought to establish it as a respected scientific field and stakeholders who began to dream publicly that an extinct species could one day be resurrected. This cultural history of ancient DNA research provides the context for a case study of the Australian Museum of Sydney's highly publicized attempt to bring back the thylacine, a marsupial species that became functionally extinct in 1936. Following quickly on the controversies sparked by Dolly the Sheep in 1997, the Thylacine Cloning Project (1999–2005) introduced a broad and international public to the prospect of conquering extinction via biotechnology and amplified both concerns and hopes about the latent power of animal cloning. The chapter concludes with a discussion of the fleeting but remarkable resurrection of the Pyrenean ibex in 2003 and the implications of the de-extinction agenda.

5.2 The Past Comes Alive: Ancient DNA as Time Travel

In April 1984, *Technology Review* published a hoax article that reported the birth of two woolly mammoth calves. The author claimed that this accomplishment—especially noteworthy since the woolly mammoth went extinct approximately 11,000 years ago in the late Pleistocene era—was the result of a joint American-Soviet

experiment in which cells extracted from a frozen woolly mammoth carcass were cloned into an embryo and then implanted in and brought to term by a surrogate Indian elephant (Ben-Aaron 1984). The miraculous birth of *Elephas pseudotherias* was duly mentioned in other mass media outlets such as the *Chicago Tribune* (Mattill 1984). Though the tone of this coverage suggested that some journalists suspected that they were being teased, the editor of *Technology Review* prudently admitted to the hoax in the October 1984 issue. *Technology Review's* joke is important to mention because it coincided with the first serious reports of the retrieval of DNA from extinct species and anticipated the uneasy relationship between science fact and science fiction, and between hope and hype, that continues to complicate the field and its public reception today.

5.2.1 No Longer Dead as a Dodo

In June 1984, Russell Higuchi and his research team announced that they had successfully extracted DNA from a 140 year old quagga skin preserved at Mainz Museum of Natural History in West Germany (Higuchi et al. 1984). The quagga (Fig. 5.1), a subspecies of South African zebra, went extinct in 1883 when the last known specimen died in its enclosure at the Amsterdam Zoo. Though once abundant in the Karoo semi-desert, the quagga perished due to over-hunting as Afrikaners sought to clear land of competitor species in order to graze sheep. Higuchi's team, as noted in the prestigious peer-reviewed journal *Nature*, extracted a small amount of DNA from the pelt and also managed to sequence pieces of mitochondrial DNA (mtDNA). The article concluded that fields as diverse as paleontology, evolutionary biology, archaeology and forensic science would benefit from advances in ancient DNA research, if additional studies confirmed the long-term survival of DNA in other specimens (Higuchi et al. 1984).

This early scientific abstract did not mention using ancient DNA in order to clone an extinct species. Still, even the august *Nature* could not entirely ignore the issue most likely to intrigue the mass media and the public. In the more informal "News and Views" section of the same issue, Alec J. Jeffrey (in a commentary on Higuchi's work titled Raising the Dead and Buried), notes that "DNA sequences of bog people and Egyptian mummies would no doubt be fascinating, though cloning the latter might prove too nerve-wracking a task for the superstitious genetic engineer" (Jeffreys 1984). Though the commentary is humorous, it anticipates the way in which the idea of cloning an extinct species will soon dominate mass media accounts of ancient DNA research. Indeed, the article begins with the rhetorical question "is the quagga as dead as the dodo," concluding "not entirely, and nor indeed might be the dodo, if the remarkable findings of Russell Higuchi, Allan Wilson and co-workers reported on page 282 of this issue are anything to go by" (Jeffreys 1984). Fifteen years later, many scientists would deplore the attempt to bring back the thylacine as scientifically and ethically bankrupt, but early commentary on ancient DNA reveals that even prestigious journals tacitly acknowledged the fanciful aspects of this new research.

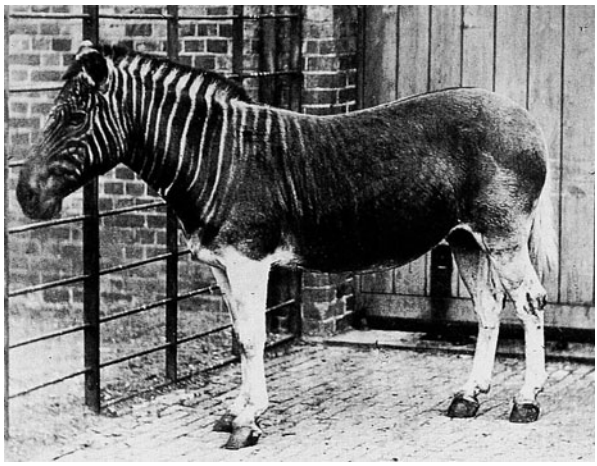

Fig. 5.1 Quagga, Regent's Park Zoo, London, 1870. By Frederick York (d. 1903) [Public domain], via Wikimedia Commons

Science News took a somewhat more cautious approach to publicizing Higuchi's findings than *Nature* did, focusing on the ability of ancient DNA research, done properly, to clarify our knowledge of the evolutionary links between extant and extinct species (Miller 1984). Nevertheless, it still saw fit to paraphrase the scientists involved in the research, who instruct readers that technological limitations and the fragmentation of the samples make "the possibility of actually bringing ancient species 'back to life'... extremely remote" (Miller 1984). Qualifiers such as "extremely remote" reflect the scientific imperative to account for probability and uncertainty; very rarely do scientists in a specific field unilaterally declare anything either impossible or inevitable. In the translation from science to the mass public, however, the language of probability can lend itself either to speculation beyond what the actual findings can bear or to the use of humor as a rhetorical device that enables a journalist simultaneously to raise a possibility, while also distancing himself from it.

One year after the publication of Higuichi's quagga study, Svante Pääbo announced results from a study of an ancient Egyptian mummy fragment obtained from the collections of the Victoria Museum for Egyptian Antiquities, Uppsala, Sweden. The results indicated that the sample contained DNA, despite being significantly degraded and chemically modified, leading Pääbo to conclude that "applying recombinant DNA techniques to the study of ancient mummified tissues might prove to be a future fruitful area of research" (Pääbo 1985a). That same year, Pääbo reported that he had successfully extracted DNA that could be molecularly cloned from a 2400 year old mummy of a child (Pääbo 1985b). *The New York Times* heralded these findings as the world's first "biochemical resurrection" and as "the most spectacular achievement of this kind to date" (Schmeck 2009). The years immediately following Higuchi's and Pääbo's essential work on the quagga and Egyptian mummies, respectively, witnessed a significant expansion of ancient DNA research and media interest in these seemingly exotic projects. Not all of these findings, often announced breathlessly by the mass media, could withstand scientific scrutiny and authentication. For example, early reports that ancient DNA had been extracted from

125 million year old specimens preserved in amber could not be confirmed and were later declared false (Penney et al. 2013). Nevertheless, as Sykes (1991) concluded in the early 1990s, "everybody is having a go—and apparently succeeding—at getting DNA from museum specimens, dried insects, mummies, old bones and fossil plants and, quite rightly, the press loves it."

Ancient DNA research began to progress rapidly after Kary Mullis's discovery of the polymerase-chain reaction (PCR) in 1985, research for which he received a Nobel Prize in Chemistry. PCR allows researchers to produce almost unlimited copies of DNA from small and often fragile samples and thus increases analytical rigor. Svante Pääbo et al. (2004) argued that "ancient DNA research, defined broadly as the retrieval of DNA sequences from museum specimens, archaeological finds, fossil remains, and other unusual sources of DNA, only really became feasible with the advent of techniques for the enzymatic amplification of specific DNA sequences," while mass media accounts often used metaphors such as a "window into the past" to describe Mullis's innovation (Browne 1991). Nevertheless, despite PCR's power, DNA degradation and contamination remained major obstacles to using ancient samples with confidence and several scientists began to focus on establishing protocols for replicable and reliable ancient DNA findings. Specimens are vulnerable to contamination from innumerable organisms that might touch them over the millennia and from the humans who attempt to extract DNA (Pennisi 2005). The contamination problem is so acute that Sykes referred to it as a "ghastly spectre" inhibiting the legitimacy of the field. He also noted that the containment facilities and procedures necessary to ensure rigorous replication of results ruled out all but the most well-funded labs (Sykes 1991), an observation that draws a strong boundary around recognized practitioners of the science. Other serious problems with ancient DNA research include inadequate experimental setup, insufficient authentication of findings and the high risk of fake-positive results (Hebsgaard et al. 2005). Yet despite all of these challenges, prominent scientists acknowledge that "the study of ancient DNA has the allure of time travel" (Pääbo et al. 2004). This allure sometimes causes even serious scientists to become mystical in describing their research and its possibilities. For example, in the *Journal of Experimental Zoology,* a French research team envisions the study of ancient DNA as a way to step through the door that separates the past from the future, a journey wherein "soon the fine structure of our innermost biological identity will be unveiled and what has so far remained deep and secret will shine like an unearthed treasure and shape and fuel our future quests" (Birnbaum et al. 2000, p. 21).

5.2.2 Everything Old is New Again

Today, ancient DNA research is an established field of scientific inquiry, with important implications for studies of migration, climate change, kinship and biodiversity. Despite ongoing challenges, ancient DNA is also an increasingly important tool in wildlife management. For example, research comparing old museum specimens of

iguana DNA to living iguanas in the Galapagos Islands contributed to a restoration project that repatriated Baltra iguanas to their original site on Seymour Island (Hofkin et al. 2003). Other examples of applied ancient DNA research include the use of museum specimens to determine the genetic diversity of the endangered Earless Dragons (Melville 2005) and a project that identified a small population of Northern right whales in the North Pacific as genetically distinct from those in the Atlantic, thus providing crucial evidence for re-classifying the former as an endangered species (Rosenbaum et al. 2000). However, as progress continues and media attention increases, it can be difficult to contain the field within the boundaries of normal science, famously defined by Thomas Kuhn (1962) as professional work that is incremental and authenticated and which provides a coherent research platform for a delimited group of credentialed experts. Ancient DNA's association with Neanderthals, dodos, woolly mammoths and mummies ensures that, in the public domain, spectacle cannot be easily separated from science.

Indeed, popular accounts of ancient DNA research take us back in many ways to the nineteenth century, when science was a also form of entertainment and experiments were performed at a variety of sites such as popular fairs, salons, learned societies and shops (Bensaude-Vincent and Blondel 2008). P.T. Barnum's FeeJee Mermaid, famously (and lucratively) exhibited in 1842 as a "genuine fake," is the distant cousin of both the digital dinosaurs and mastodons that stomp through I-Max natural history documentaries today and the futuristic woolly mammoths that keep popping up in newspaper reports around the globe. Another parallel example drawn from an earlier century is the ballooning craze that captivated audiences in Europe and America, mocking early attempts to draw boundaries between science and entertainment since no one could agree whether these ascents were scientific experiments or glamorous publicity stunts (Olivetto 2007). To refer to ancient DNA research as a "populist science" (Wayne et al. 1999) is therefore doubly accurate: conflating ancient DNA research with conquering extinction attracts a level of interest that eludes most hard sciences, while promises of resurrected Tasmanian tigers and passenger pigeons puts us right back at the fairgrounds, spectators eager to see what is behind the showman's curtain.

The phenomenal global success of Steven Spielberg's film *Jurassic Park* (Amblin Entertainment 1993) decisively elevated the mass visibility of ancient DNA and animal transgenics, creating in the process a potent metaphor that continues to resonate. Based on Michael Crichton's novel (1990), the film spun-off three financially successful sequels and inspired a popular theme-park ride at Universal Studios. Crichton's novel, a best-seller, was ostensibly based on an idea mooted by Dr. George O. Poiner, Jr., a paleontologist at the University of California at Berkeley. Dr. Poiner and his wife, Dr. Roberta Haas, achieved scientific fame for their study of a 40-million-year-old piece of amber that contained well- preserved gnat tissue. Subsequent research, as noted, cast doubts on the viability of such extraordinarily old specimens. Moreover, the barriers to scientists bringing back a dinosaur remain technically insurmountable. Not only is dinosaur DNA inevitably too old and too degraded to use for cloning, there is an obvious problem inherent in trying to locate a surrogate mother for a Tyrannosaurus Rex (or even a T-Rex egg). Still, in the initial

heady rush of ancient DNA research in the early 1990s, Dr. Poiner stated in the *New York Times* that " 'I think the idea is quite plausible and I feel the possibility for doing something like this will exist in the future' " (Browne 1991). Both the novel and the film skillfully wove highly selective aspects of this provisional scientific research (particularly those pesky mosquitoes preserved in amber) into an adventure narrative that paid homage to Cold War popcorn classics such as *The Lost World* (1960, based on Sir Arthur Conan Doyle's 1912 novel) and *King Dinosaur* (1955). Jurassic Park, by far the most frequently used metaphor in mass media articles about ancient DNA research, continues to provide both an accessible hook to grab audience attention and a way of translating complex scientific findings across different national contexts and languages.

Even as most palaeobiologists try to keep the public focused on ancient DNA's merits as a tool for studying evolution and climate adaptation, the Jurassic Park metaphor dominates mass media coverage of this new science. Pääbo et al. (2004), for example, emphasize that the use of ancient DNA should be premised on a legitimate biological question and not on novelty value. However, the promissory aspects of ancient DNA continue to tantalize the mass media, the public, entrepreneurs and, increasingly, even a few well-respected scientists who now discuss openly the possibility of bringing back a recently extinct species. The recent emergence of the de-extinction debate reflects an enduring Western preoccupation: what *if* science ultimately provides us with the ability to resurrect the dead? As Anna Meyer (2005) wonders in her book *Hunting the Double Helix: How DNA is Solving Puzzles of the Past*, "might we one day create a 'prehistoric zoo' in which monkeys mix with mammoths, and tigers with thylacines? Does extinction have to mean forever?" The following analysis of the Thylacine Cloning Project demonstrates that even as the scientific answers to such questions remain elusive, the political and ethical problems introduced by the idea of bringing back an extinct species are downright wicked.

5.3 Tasmanian Tiger Tales

Dolly the sheep, her birth announced to the world by the Roslin Institute in January 1997, was received with approximately the same level of international media fanfare as attends the arrival of a direct descendent to the British throne. Ian Wilmut, Keith Campbell and Colin Tudge (2001), the scientists primarily responsible for Dolly, saw her as the harbinger of the new "age of biological control" in which "human ambition will be bound only by the laws of physics, the rules of logic, and our descendents own sense of right and wrong." Joseph Rotblat, a Nobel Prize winning nuclear physicist, likened Dolly to the atom bomb in terms of her scientific significance and the dangers inherent in somatic-cell nuclear cloning (SCNT), while the Vatican deplored her as an abomination. As discussed in chap. 4, Dolly was a particularly disruptive scientific breakthrough since, just by standing there in her paddock, she embodied the transgressing of a boundary (reproductive cloning of a mammal) that we had been told was immovable.

Less than 3 years after the public furor over Dolly the Sheep, and 15 years after the first reports of the extraction of quagga DNA, the Australian Museum in Sydney launched its Thylacine Cloning Project on 7 September 1999. The timing was apt. September 7th, the day the last known thylacine (colloquially known as the Tasmanian tiger) died in captivity at Hobart Zoo in 1936, is commemorated in contemporary Australia as National Threatened Species Day. Tapping into this iconography, the project was presented to the public by the Museum and its corporate backers as an attempt to use the newly established tools of ancient DNA extraction and somatic-cell nuclear cloning to bring back the thylacine and restore it to the still-extant Tasmanian wilderness.

Yet from the outset the project's scientific rationale, which was vigorously disputed by some stakeholders, became inextricably tangled up in Australia's complex environmental politics and history. The project also reflected a new, neoliberal era of diminished Government support for public museums and a concomitant need to attract new (primarily corporate) funders. The Discovery Channel was an early financial backer of the thylacine cloning project, obtaining proprietary rights to make a documentary about the initiative. For project advocates, including the Australian Museum Board, the interplay of scientific, environmental and commercial interests represented a necessary and innovative response to the new economic conditions confronting museums. If a Tasmanian tiger actually loped out of the Museum as a result of the project, so much the better for the bottom line, for science and for biodiversity. Critics, however, argued that the promise of resurrected thylacines was a cynical way to garner public support for a project that was neither scientifically feasible nor ethically sound. Ultimately, the battle over whether to try cloning the thylacine became a battle over which stakeholders owned the Tasmanian tiger story and what limits, if any, should be placed by society on technological and scientific experimentation.

5.3.1 You don't know what you got until you lose it

To the European colonists who arrived in Australia in the early nineteenth century, the continent seemed infinite, exotic and often forbidding. Taxonomies developed for European species did not seem to account for such fantastical creatures as the platypus and kangaroo or the Tasmanian tiger (actually a marsupial that, via convergent evolution, had evolved to become a top-level predator and to occupy a niche similar to that of the wolf in North America). In 1824, the Van Diemen's Land Company (Netherlands) brought sheep farming to Tasmania, initiating a series of events by which the thylacine would be functionally extinct by the mid 1930s. Though today the significance and extent of thylacine predation on sheep herds is vigorously contested (Owen 2004; Paddle 2000), in the nineteenth century the Tasmanian tiger quickly became an easy scapegoat for livestock losses and the associated loss in income. By 1830, the Van Diemen's Land Company had introduced bounties to incentivize hunting and exterminate the species. In February 1888, the Tasmanian

Fig. 5.2 Tasmanian Tiger (Thylacine) Killed by Clem Penny. Date unknown. (Courtesy of Tasmanian Archive and Heritage Office, PH30-1-6303, http://www.linc.tas.gov.au/tasmaniasheritage)

Parliament introduced a reward of one pound for a dead adult thylacine, raising the bounty three months later to $\leq$ two pounds per dead animal in order to match the private scheme introduced by the Glamorgan Stock Protection Association. By 1909, when the Government bounty scheme formally ended, 2184 bounties had been paid and the Tasmanian tiger population had been thinned precariously. In the late nineteenth century, the thylacine's (Fig. 5.2) eradication was framed as a victory for farmers and (implicitly) for the "civilizing mission" of colonialism. *Scientific American*, for example, asserted in 1890 that Tasmanian farmers had to defend their livestock against "such terrible enemies" and confidently predicted that the thylacine would soon disappear as had the wolf in Europe (Onstalet 1890, p. 105).

5.3.1.1 The Thylacine as Environmental Icon

In 1926, the London Zoo purchased its last Tasmanian tiger for 150 pound. The bounty schemes of the previous decades had decimated the population so successfully that the animal's monetary value rose in tandem with its declining numbers. The end of the thylacine also converged with the slow but inexorable shift among the settler families from a colonial to an Australian identity. The kangaroos, koalas and

thylacines that had seemed so bizarre a generation or two earlier became icons of a rugged but unique natural environment, an indigenous Australian environment that needed to be preserved and celebrated.The proliferation of motion pictures and still photography in this era also meant that remnant thylacines could be captured on film, creating an emotional immediacy that scientific articles and paintings had not.

The thylacine saga became a powerful environmental fable because it is easy to imagine an alternate past in which the Tasmanian tiger survived, had humans acted with just a bit more urgency. In 1927, Clive Lord (Secretary to the Tasmanian Advisory Committee on Native Fauna) reported to the Royal Society of Tasmania that though a small population might find respite in the unsettled Western outback, " 'its eventual doom seems apparent' " (Harper 1945, p. 41). In 1928, the Tasmanian Parliament passed *The Animal and Birds Protection Act*, a significant legislative milestone that reflected growing concern about the colonial toll on indigenous fauna. Species accorded full protection included the flying squirrel, platypus, Tasmanian great kangaroo and Tasmanian porcupine, each of them unique to Australia. Partial protection was given to kangaroos, deer, wallaby and ringtailed possums. Predators did not fare as well under the law, reflecting political tensions between early preservationists and the farming and hunting industries. The unprotected species included foxes, kangaroo rats and the wombat, as well as the "native tiger" (thylacine) and the Tasmanian devil. Nevertheless, the Animal and Birds Protection Act provided an essential platform on which concerned citizens and scientists could petition for the Tasmanian tiger. On 10 July 1936, after consistent advocacy by the Tasmanian Advisory Committee on Native Fauna, the Tasmanian government transferred the thylacine to the fully protected category, but it was too late. The last documented Tasmanian tiger died in its Hobart Zoo enclosure 59 days later. In 1986, the International Union for the Conservation of Nature formally listed the thylacine as an extinct species.

For approximately 60 years, this fable had a beginning (the primordial innocence of pre-colonial Australia), middle (colonial aggression towards native fauna), and end (the last captive Tasmanian tiger slipping away alone and unattended, one unseasonably cold evening at Hobart Zoo). The lesson drawn from the story was that the thylacine, now gone forever, should be commemorated as a symbol of all of the Australian species that still desperately needed environmental protection. When the Australian Museum lobbed ancient DNA and cloning into this complex mix, it had the cultural effect of a Molotov cocktail. Even to suggest that science might now provide a way to bring back the thylacine was a political act because it threatened the primacy of those who had spent their professional careers on habitat preservation and undermined the dominant narrative of Australian environmental history. The thylacine cloning project also emerged in a postcolonial context in which questions of colonial responsibility for the near total destruction of Aboriginal culture infused virtually every public debate on social policy. Consequently, not everyone responded to the idea of bringing back the thylacine with unalloyed enthusiasm (a fact that seemed to catch the Australian Museum off-guard), while the question of who controlled the thylacine myth became the ground upon which the scientific merits of the project had to contend. Almost two decades later, the public reaction to the project might seem

overdrawn to us but, against the immediate fact of Dolly the Sheep and the fiction of *Jurassic Park*, the thylacine initiative struck several cultural nerves at once and drew an international public into the sphere of this new and promissory science. Like a figure in a painting suddenly made animate, the thylacine jumped out of the frozen past to become the symbol of environmental redemption through biotechnology. This usurpation of the thylacine's meaning blurred the boundaries between science and politics, science and science fiction, past, present and future, and expertise and lay knowledge.

5.4 Spectacular Science

The research plan for the thylacine cloning project anticipated using sophisticated biotechnological tools, ranging from ancient DNA extraction via PCR to reproductive cloning of a thylacine via a surrogate animal such as the Tasmanian devil. However, both the idea and implications of ancient DNA received by far the most media attention. The Australian Museum identified two early milestones for the project: (1) extracting viable thylacine DNA from specimens stored in the Museum archives, and (2) constructing a genomic library from the isolated DNA. The Museum's annual report for 1999/2000 highlights the new initiative, focusing in particular on the extraction of purportedly high quality DNA from a specimen found in the Museum's basement (Australian Museum 2000). Dr. Don Colgan, Head of the Evolutionary Biology Unit and lead scientist on the project, acknowledged the very low probability that a thylacine would actually saunter out of the laboratory as a consequence of the research. Nevertheless, he stated to the BBC that the Museum hoped "to clone animals in sufficient numbers to release a self-sustaining population into one or more of the many suitable habitat areas remaining in Tasmania" (Colgan 1999). Throughout the project, the goal of thylacine cloning teetered on the ethical tension between acknowledging the limits of the specimens and the science versus promulgating the rhetoric of hope that legitimized the Museum's appeals for media attention and funding.

The New South Wales Government provided $20,000 AUD of start-up funding for the initiative, which was supplemented by the Discovery Channel and by an undisclosed donation by the private Rheuben Griffiths Trust. Bob Carr, the Premier of New South Wales at the time, connected the project directly to the extinction crisis, exclaiming that " 'we are entering the sixth great age of extinction and we are seeing biodiversity disappear before our eyes. We have the prospect of bringing one of God's creatures back to life and I can't think of anything more remarkable' " (Benson 1999). Over its duration, the project did reach a few of its projected milestones. For example, approximately 200 ng of liver DNA was extracted from specimen P762 and Don Colgan announced in May 2000 that enough DNA had been obtained from the specimen to move to the second stage of the cloning process, synthesizing entire chromosomes. In 2002, however, amplification of the liver DNA indicated high levels

of contamination. In February 2005, the Museum ended the project, citing a lack of proper facilities and the overall poor quality of the available DNA.

Throughout the project, the Museum's narrative of environmental redemption through technoscience faced fierce resistance. Using the Tasmanian tiger to promote the research project guaranteed publicity, but ultimately the proliferation of viewpoints and stakeholders could not be contained within the Museum's orchestrated narrative of hope and technological progress. As I argued in a previous article, "given both the iconic status of the Tasmanian tiger and the fact that the Australian Museum was the first major research organization in the world to state openly that it hoped to clone an extinct species, the project easily slipped the boundaries of normal science and fell into the messy public space of post-colonial and environmental politics" (Fletcher 2008, p. 198). As early as September 1999, Dr. Greg Pike (Southern Cross Bioethics Institute) argued that serious questions needed to be raised about creating life simply for spectacular science (Barbeliuk 1999a). Nick Mooney, Wildlife Manager for the Tasmanian National Parks and Wildlife Service, castigated the project as a technological fix that only further distanced human beings from the environment (Mooney 2002). Similarly, a *Sydney Morning Herald* (SMH) editorial asked, "what do you do with a Tasmanian tiger in modern Australia? The same sheep farmers that encouraged its extinction are unlikely to be happy to have neighboring national parks crawling with a creature drooling over their lambs" (SMH 1991). From the start, the Museum's strategy of framing the project as normal science ran into unexpected social resistance, illustrating Brian Wynne's argument that visible debates about science often involve crucial differences about "what questions knowledge should be addressing, and thus what (combinations of) knowledge should be in play" (2008, p. 24). The pretext of resurrecting the Tasmanian tiger ignited media interest, which Museum annual reports suggest was a deliberate goal, but such widespread intrigue in the end could not be effectively managed. Diverse stakeholders reacted ambivalently to the idea of "bringing back" the thylacine, indeed to the idea of "conquering" extinction at all, and they couched this ambivalence through strong contestation of both the scientific credibility and moral legitimacy of the project.

The ongoing struggle between science and spectacle occurred at two levels: between science (as represented by the Museum's narrative) and the public, but also within science as well. Sympathetic media accounts juxtaposed arguments about the scope and authority of biotechnology with the admittedly enticing idea of resurrecting an extinct species. In 2002, for example, an editorial in the Sydney Morning Herald asserted that "good science will be done, even if no baby thylacine crawls out of the test-tube. This is a proud moment for Australian scientists. It would be churlish to dismiss the museum's work as a publicity stunt or too far-fetched to ever see the light of day" (Dayton 2002). Indeed, just as the thylacine now represented Tasmania (it is even the brand of the Department of Primary Industries, Parks, Water and Environment), many commentators equated the ambitious cloning project with the status of Australian science. Mike Archer, for example, referred to the extraction of DNA kidney and liver fragments from the bottled specimen as " 'the biological

equivalent of man taking his first steps on the moon' " (Taggart 2000), while the Sydney Morning Herald mused that "in a world where people have gone to the moon, flown faster than the speed of sound and invented palm-sized computers, then surely re-animating a bag of bones and fur is within our grasp" (SMH 1991).

Yet many scientists worked actively to undermine the fundamental premise of the project (that extinction could be "conquered") and to wrest back authority over the proper scientific use of ancient DNA analysis. Against the backdrop the thylacine cloning project, H. Nicholls noted in *PLOS Biology* that "there is still concern that many studies are not paying enough attention to the exacting protocols needed to overcome the technical challenges of the discipline and to defend it from the ridicule that has plagued it in the past" (Nicholls 2005, p. 0192). Professor Alan Cooper, who has conducted well-respected ancient DNA research on the dodo and other extinct species, publicly admitted to " 'very negative feelings about such work, but don't think I should go into too much other than to say it's not going to work and it's a total waste of time' " (Williams 2001). Nevertheless, while the scientific critiques of the project were often severe, all sides worked within the DNA-as-code metaphor that had guided research in molecular biology since at least the 1950s. Jeremy Austin (Natural History Museum in London), for example, compared the likely fragmentation of the thylacine DNA samples to " 'typographical errors in a piece of writing making words nonsense' " (Barbeliuk 1999b) and to " 'taking a set of encyclopedias and tearing up all the pages, then burning nine out of ten of them' " (Webb 1999). Mike Archer, however, countered that " 'this is not an issue of putting together the Hong Kong telephone book that's been cut up into little letters, this is big sections of the book that have been pulled apart' " (Williams 2001). For both believers and skeptics, the worth of the thylacine specimens revolved around the degree to which the instructions for making a Tasmanian tiger could be read from the DNA.

The scientific back-and-forth between those who thought some good science would emerge from the project and those like Jeremy Austin (Natural History Museum in London) who believed that "cloning a thylacine is and always will be impossible" (Barbeliuk 1999b) was further complicated by contradictory predictions by the Museum's Director, Dr. Mike Archer. For example, in response to a question regarding whether cloning projects could substitute for conservation efforts, Archer admitted in 2003 that " 'we have no idea whether this project is going to succeed' " (Saunders and Saunders 2003, p. 16). Yet the *South China Morning Post* has Dr. Archer stating that he believes a thylacine could be cloned within 10 years (Squires 2004), a prediction repeated in numerous stories on the project. Such speculation not only courted the type of scientific ridicule feared by some palaeogeneticists, but also became the twenty-first century equivalent of the more than 4000 alleged sightings of the thylacine that have occurred in Tasmania since 1936. Couched in disclaimers such as "could," "maybe" and "probably not," the various expert opinions proffered began to seem just that—opinions, telling the reader more about the state of uncertainty and competition surrounding this young research field than about whether the thylacine could or should be cloned. Paul Keen, in a sublime discussion of the balloonmania that gripped England in the eighteenth century, shows how ballooning incurred the wrath of scientists and intellectuals because

they feared it would inspire mass delusion, that it substituted technical trickery for serious science (Keen 2006). At the turn of the twenty-first century, the scientific discussions that surrounded the thylacine cloning project also turned on the desire by many researchers to police the boundary between science and spectacle, lest a gullible public be seduced into thinking that ancient DNA and cloning were forms of alchemy that could turn an ancient string of chemicals into a real, breathing animal.

5.5 Pickled Pups and Promises

Though it the Australian Museum tried to position its thylacine research firmly within the boundaries of legitimate science, the media attention it courted inevitably created conflicts. By putting the project so firmly in the public arena in advance of any scientific publications, the Museum created a platform upon which critics could repeatedly excoriate it. The Tasmanian tiger, which had already served Australia as a nineteenth century scapegoat and as a twentieth century postcolonial icon, now became the twenty-first century symbol for scientific hubris. The story and image of the "pickled pup" only further complicated the distinction between science and spectacle. The digital image of this specimen, which had fortuitously been preserved for over a century in a jar of alcohol (formaldehyde, more commonly used in the nineteenth century, would have destroyed the DNA), figured prominently in media accounts of the cloning project. For example, the *Globe and Mail* reported, "hope for the rebirth of the tiger... lies in the murky depths of a museum specimen jar, where a 6-month old thylacine pup has been preserved in alcohol since 1866" (Hopkins 2000). Ultimately, three specimens were used in the project: the ethanol preserved pup (specimen P762), a dried male specimen (M822), and M27836, an unsexed dried specimen.

Critics of the project noted that even though the pickled pup actually yielded neglible amounts of DNA (the research relied primarily on the dried specimens), it remained "the project's de facto icon... featured prominently in the commercial documentary on the project" (Greer 2009, p. 31). Archer referred to the pickled pup specimen as " 'the miracle bottle in which this time capsule is just waiting to pop back into life,' " and even suggested that " 'at the rate at which this technology is increasing, I wouldn't say there's any reason why we shouldn't expect to be able to go into a pet shop and buy a pet thylacine and bring it home' " (Kezwer 1999, p. 680). As the Museum Director, Professor Archer was doing exactly what a self-sustaining museum requires of its high-level administrators by acting as a "science populariser," someone who can no only explain science in laymen's terms but also effectively communicate the "dimension of human adventure" (Rivera 2000, p. 1) that inspires scientific research. For all the criticism that Archer received during the Thylacine Cloning Project, the populariser role is essential to the success of the modern museum and goes back to at least to P.T. Barnum (1810–1891) and the initial rise of modern media. Henry Fairfield Osborn (1957–1935), an American eugenist

and palaeontologist, pioneered a unique blend of science and visual spectacle in order to entice visitors to the American Museum of Natural History. Drawing on the popular science fiction of his day, Osborn presented science as a quest, an exciting adventure story in which Museum spectators played an essential role (Sommer 2009). The Australian Museum was thus not doing anything unheard of when it launched a thylacine exhibit titled "See It Now While Its Still Extinct," but both the timing of the initiative and the use of such a totemic animal generated a scientific backlash that put the Museum from the outset into a defensive posture with respect to its ultimate intentions.

Annual reports from this time period provide additional evidence of a strong incentive for the Museum to emphasize the science populariser role, since they document that it was under extraordinary financial pressure in the late 1990s. From the outset, the thylacine cloning project operated behind-the-scenes at the intersection of the old institutional mission to preserve the past while educating the public and the new imperative to justify fiscal performance to the Government. The Museum Director's Message in the 1998/1999 annual report emphasizes the "growing list of sponsors" for the thylacine project, while the 1999/2000 report is replete with references such as "new friends in the corporate and private sectors of the community," "relevance to the needs of a rapidly changing world," "financial viability," and the need to position the Museum "within the crowded market by creating joint promotions with corporate sponsors." The 2001/2002 annual report refers to the "unprecedented worldwide media attention" accorded the thylacine project and also to the fact that the Discovery Channel's thylacine documentary aired in 155 countries.

Several critics noticed that Museum announcements of groundbreaking advances in various media outlets usually coincided with both the airing of the documentary on national networks and deployment of the image of the pickled pup. An article in *The Australian*, for example, noted that the so-called breakthrough filmed at the end of the documentary involved getting the polymerase chain reaction technique to work on the Museum's specimens, not on thylacine DNA for the first time—a distinction that made the Museum's purported accomplishment rather banal in scientific terms. The article also quotes the Discovery Channel's vice president of programming, who admitted that, "we needed to have a breakthrough to make the story worth telling." A critical report on Wired.com took both the documentary and overall commercial aspects of the project to task, referring to it as "manna from heaven as a profile raiser. By adroitly rebranding arcane genetic research into a kind of neo-sacred journey to restore lost Arcadia, the Australian Museum has magically attracted private funding to its work (Taggart 2002)."

Such commentary (Taggart 2000) contradicts Allan Greer's assertion that the media "rarely looked deeply and were never overtly critical" (2009, p. 35) of the project. Not every reporter had the training to critique the project in precise scientific terms, but numerous journalists and editors refused to accept the feasibility of the project at face value and, when engaging with the idea of a cloned thylacine, opened up the debate to contest its scientific and ethical claims. Scholarly critics also weighed in through the mass media. The *Sydney Morning Herald*, for example, published a

commentary by Lesley Head, then associate professor of Geosciences at the University of Woolongong, who asked, "Where could this poor creature survive but in the contemporary equivalent of a glass case (Head 2000)?" A subsequent editorial in the same newspaper engaged with the spectacular idea of an actual thylacine clone, but then referenced previous problems with animal transgenics by skeptically asking, "Will it be an abomination that ages as fast as Dolly the Sheep, dies of cancer, or carries crippling deformities that result from the re-ignition of DNA that has been in slumber for a century" (SMH 1991). Analysis of both domestic and international media accounts indicates that positive comments from Museum advocates and scientists were frequently disputed or critiqued by highly skeptical scientists and conservationists.

The overall pattern revealed by in-depth media analysis ultimately reveals not that journalists were gullible or lazy in reporting on the project, but that their reporting reflected the very ambiguity that characterized the purpose of the project in the first place. Their challenge was to provide a balanced report on a project ostensibly premised on science, while also acknowledging the fantastical elements of the story as told by the Museum. Few journalists wanted to repeat the credulous reporting that propelled the 1984 woolly mammoth hoax, especially since science *had* progressed significantly since the mid 1980s. Reporters were often reluctant to declare that cloning the thylacine was impossible (remembering the surprise of Dolly the Sheep), nor did they seek to be enrolled in promulgating a fiction.

The evocative image of the pickled pup ultimately played an important role in initially stoking and then maintaining media interest. As Karen Firestone, a scientist associated with the project, commented, a "pickled pup is more photogenic than a bone" (Firestone 2004). The image of the fetal specimen was also a compelling visual because it appealed to the secret desire we all share to find a Picasso in the attic, to exult in that moment when the old, seemingly worthless artifact stacked amidst all of the junk is revealed as priceless. The pickled pup image vividly embodied the dream that propels any project that seeks to resurrect an extinct species: the hope that a dusty old jar in a Museum basement will turn out to contain an elixir of life that will allow us to bring back all those species whose loss now haunts us. As both an image and an artifact, the pickled pup encapsulated the idea of "precious DNA" waiting "ever so patiently" (Archer 2005, p. 13) for science to catch up with the tools that can decipher its message.

5.6 Reviving and Restoring

In 1844, a few years after P. T. Barnum's FeeJee Mermaid hoax delighted audiences, Edgar Allan Poe stirred the public imagination anew with his infamous balloon hoax. Poe, then a young journalist, claimed that the Atlantic Ocean had finally been crossed by balloon, and declared: "The great problem is at length solved! The air, as well as the earth and the ocean, has been subdued by science and will become a common and convenient highway for mankind." Two days later, on 15 April

15 1844, the *New York Sun* was obliged to publish a retraction, noting that "the mails from the south. . . not having brought confirmation of the balloon from England. . . [inclines us] to believe that the intelligence is erroneous" (Goldman n.d.). At the turn of the twenty-first century, intelligence about the thylacine cloning project was also difficult to confirm, despite both the intense publicity surrounding the project and the confident proclamations of the Australian Museum. When the thylacine cloning project left the lab and entered the public domain, it could not be contained within the Museum's preferred frames of scientific progress and environmental restoration. The project's most visible proponents quickly lost control of the project's social meaning and significance, as the mass media effectively broadened the official frames to include a range of considerations, including the use of biotechnology in conservation, the limits of ancient DNA as a scientific tool, the ethics of attempting to rewrite the environmental past through technology, and the finality of extinction.

B. Wynne (2001) argues "we cannot properly conduct relevant research on publics in relation to science, unless we also critically examine the elephant in the room—what is the 'science' which are supposing that people experience and sense in each of these situations" (Wynne 2001, p. 21). In this case, we have to deal with the tiger in the room. Throughout the project, the science of ancient DNA and cloning could not be separated from social anxieties regarding both extinction and biotechnology and from ongoing Australian guilt about the thylacine. Proposing to conquer extinction conjured explosively with what many believed was the last incontrovertible fact—the finality of death. Yet where the *Sydney Morning Herald* saw extinction as "life's ultimate form of discipline," for Museum Director Archer the ultimate success of the cloning project "would challenge the whole notion of extinction. It would challenge the whole notion of death for that matter" (ABC Online 2005).

Scientists, as stakeholders, may hope to contain biotechnological debates within fixed boundaries of credentialed expertise; however, in cases that attract strong media interest and also involved the vexed question of charismatic species, expertise invariably spills over into politics and society, and the closed world of expert scientific inquiry opens up into messy disputes that shape how science is understood and practiced in society. Research on stem cells, cloning, and synthetic biology (among many other subjects) continues to be promoted by corporations and the mass media as the key to solving intractable problems from climate change to cancer. In this context, the idea of "conquering extinction" slips effortlessly into the stream of potential good news. Though Museum scientists used the thylacine to attract support (financial or otherwise) and international attention, the public effectively substituted its own concerns about whether or not anyone should rewrite the past. Meanwhile, the animal itself, present and absent throughout, hovered like the Cheshire cat's grin over the proceedings, its smile widening a bit at the news on 20 May 2008 that a University of Melbourne research team "has broken new ground, extracting genes from the extinct Tasmanian tiger and bringing them back to life in another living creature" (ABC New 2008).

5.7 See It Now, While It's Still Extinct

In March 2013, *Mother Jones* listed the thylacine as one of "12 animals we wish we could de-extinct" (Mother Jones 2013). The idea referenced the highly publicized March 2013 TEDx De-Extinction event held in Washington, DC (co-hosted by the National Geographic Foundation and The Revive and Restore Foundation) in which prominent scientists, conservationists and ethicists discussed seriously the prospect of "bringing extinct species back to life." Approximately a decade after a new Australian Museum Director quietly closed the door on the thylacine cloning project, the animal—along with distant cousins like the passenger pigeon and the woolly mammoth—was suddenly everywhere again, a symbol of the new de-extinction agenda. Though the idea remains controversial, it is far more respectable now than it was when Mike Archer first put the pickled pup before the world's media. For example, Ben Novak, Beth Shapiro (University of California, Santa Cruz) and George Church (Harvard University) are collaborating on a project to sequence the passenger pigeon genome and hope to use the cloning methods pioneered with Dolly the Sheep to bring back the species through the use of a closely related surrogate. Revive and Restore, co-founded by Silicon Valley entrepreneur Ryan Phelan and conservationist Stewart Brand, describes its mission as coordinating the work of molecular biologists and conservation biologists "so that genomic conservation can move ahead with the best current practice, plenty of public transparency, and the overall goal of enhancing biodiversity and ecological health worldwide" (The Long Now Foundation 2013). It is a primary sponsor and advocate of the passenger pigeon genome project. Of course, only time will tell if Dr. Mike Archer, now a Professor at the School of Biological, Earth and Information Sciences at the University of New South Wales, is remembered as the P. T. Barnum of thylacine cloning or the Ian Wilmut, though lately the smart money seems to be on the latter.

Indeed, in one sense, the extinction threshold has already been crossed. The Pyrenean ibex (also known as the bucardo) experienced a very brief but significant respite from extinction in 2003. The bucardo (*Capra pyrenaica pyrenaica*) is an extinct wild goat that once roamed the Spanish Pyrenees. Identified as one of four subspecies of Spanish ibex (*Capra pyrenaica*) by Professor Angel Cabrera in 1911, the population began to decline precipitously by the mid twentieth century. An initial campaign to save the remnant population through *in situ* conservation methods failed. The local Aragon Government, with support from the European Union, then decided in 1989 to capture all remaining bucardo in order to breed them via assisted reproduction in captivity. However, only three female specimens survived by this point and attempts to breed them with males of the *Capra pyrenaica hispanica* subspecies were unsuccessful. The Spanish Government declared the bucardo officially extinct in 2000, after the last female died.

That year, a team of European researchers conducted two experiments to clone the bucardo, using DNA from skin samples presciently taken from the last specimen in 1999. Together the two experiments produced 439 embryos, of which 57 were

implanted in domestic goats. The one kid brought successfully to term lived approximately seven min before dying of lung defects. Analysis of nuclear DNA confirmed that the cloned goat was genetically identical to the bucardo donor cells. The abstract to an article published about this research simply states that "to our knowledge, this is the first animal born from an extinct subspecies" (Folch et al. 2009, p. 1026), belying the intense media interest the research caused when it was formally released in the peer-reviewed journal *Theriogenology* in 2009. *The Telegraph* reported that the breakthrough "has raised hopes that it will be possible to save endangered and newly extinct species by resurrecting them from frozen tissue" (Gray and Dobson 2009). This assertion mirrored the scientists' conclusion that cloning, though inefficient, is the only way to avoid the complete disappearance of species like the bucardo, hence the necessity of banking the somatic cells and tissues of all endangered species (Folch et al. 2009, p. 1033).

From a scientific point of view, the fact that very recent skin samples, saved and stored according to expert protocols, were available to the researchers means that the cloning of the bucardo is a noteworthy achievement, but one that follows logically and incrementally from earlier research on somatic-cell nuclear cloning of sheep and other extant mammalian species. Culturally, the bucardo case is an important moment in the emerging biopolitics of extinction because it weakens, gently but decisively, the definitive boundary between extant and extinct that is essential to how we currently think about our responsibility to protect other species and to modern conservation practice. The African Wildlife Foundation, for example, reminds us in a 2013 appeal for support to save African elephants and rhinos that "once these animals are gone. . . they're gone forever," a plea for both attention and urgency that underpins the work today of zoos, environmental non-profit organizations, wildlife preserves and large-scale organizations such as the International Union for the Conservation of Nature (IUCN). The bucardo born in 2003 may have lived only a few minutes, but the fact that it existed at all has profound implications for the human relationship to nature and wilderness and for the means that we prioritize to save biodiversity. Indeed, in 2013, the Aragon Hunting Foundation signed an agreement with the Centre for Research and Food Technology in Spain to continue to test whether or not the extinct mountain goat can be cloned from preserved cells.

R. C. Lewontin, in *The Doctrine of DNA: Biology as Ideology*, argues that science "provides us with new ways of manipulating the material world by producing a set of techniques, practices and interventions by which new things are produced and by which the quality of our lives is changed" (Lewontin 1991, p. 4). If science becomes capable of consistently cloning not only the endangered but also the recently extinct, then human manipulation of the material world enters a new era. To establish a viable population of a formerly extinct species would not only change wildlife preservation as it is currently practiced but also redefine the boundaries that separate the past, the present and the future. Broadly speaking, if extinction was a philosophical problem for the Ancient Greeks, a scientific problem for Victorian naturalists and a political problem for the twentieth century, we seem now to be on the technological cusp of turning extinction into an engineering problem. Such an approach would prioritize technical questions such as how to improve cloning outcomes and how far back and

from what specimens viable nuclear DNA can be retrieved. Genomic conservation could radically expand the conservation tools available to practitioners, but fear lies in the potential that the spectacle of genomic conservation will distract us from the far less glamorous work of habitat preservation and political negotiation. Ricardo De Vos reminds us that extinction is a natural process, but it is today also "a social and cultural process calling into question notions of agency and responsibility" (De Vos 2007, p. 184). The concluding chapter explores these themes of agency and responsibility, moving our focus from attempts to bring back the recently extinct to the dream that, perhaps, even the woolly mammoth will be able to join the bio-menagerie of the future.

References

ABC News (2008) Tasmanian tiger DNA comes alive in a mouse, 20 May 20. http://www.abc.net.au/news/stories/2008/05/20/2249778.htm?section=justin. Accessed 7 Aug 2008

ABC Online (2005) The extinction of extinction. Broadcast on 22 March

Archer M (2005) Not dead, just stuffed. Bulletin 123:13

Australian Museum (2000) Annual report 1999/2000. http://australianmuseum.net.au/document/19992000-Annual-Report/. Accessed 12 May 2014

Barbeliuk A (1999a) Ethical issues may halt tiger cloning. The Mercury, 21 September

Barbeliuk A (1999b) Thylacine cloning hit as mission impossible. The Mercury, 10 September

Ben-Aaron D (1984) Retrobreeding the woolly mammoth. Technol Rev 87:85

Bensaude-Vincet B, Blondel C (eds) (2008) Science and spectacle in the European enlightenment. Ashgate Publishing, London

Benson S (1999) Test tube tiger: extinct thylacine to be cloned. The Daily Telegraph, 8 September

Birnbaum D, Coulier F, Pebusque MJ, Pontarotti P (2000) Palaeogenomics: looking in the past to the future. J Exp Zool 15(288):21–22

Browne MW (1991) Scientists study ancient DNA for glimpses of past worlds. The New York Times 25 June:C1

Colgan D (1999) Return of the thylacine. BBC Online. http://www.bbc.co.uk/print/science/genes/gene_safari/clone_zone/tastiger.shtml. Accessed 17 Aug 2004

Dayton L (2002) With a tiger in the tank. The Australian 29 May 2002. http://www.worldpress.org/asia/633.cfm. Accessed 4 Sept 2014

De Vos R (2007) Extinction stories: performing absences. In: Simmons L, Armstrong P (eds) Knowing animals. Brill, Boston, pp 183–195

Fletcher A (2008) Bring em back alive: taming the Tasmanian tiger cloning project. Technol Soc 30(2):194–201

Firestone K (2004) Email correspondence with Amy L. Fletcher, 10 September

Folch J, Cocero MJ, Chesne P, Alabart JL, Dominquez V, Cognie Y, Roche A, Fernandez-Arias A, Marti JI, Sanchez P, Echegoyen E, Beckers JF, Bonastre AS, Vignon X (2009) First birth of an animal from an extinct subspecies (Capra pyrenaica pyrenaica) by cloning. Theriogenology 71:1026–1034

Goldman S (n.d.) The great balloon hoax. http://www.historybuff.com/library/refballoon.html. Accessed 25 May 2010

Gray R, Dobson R (2009) Extinct ibex is resurrected by cloning. The Telegraph, 31 January. http://www.telegraph.co.uk/science/science-news/4409958/Extinct-ibex-is-resurrected-by-cloning.html. Accessed 13 May 2014

Greer A (2009) Cloning the thylacine: not quite a showpiece of Australian science. Quadrant 53(7/8):28–39

Harper F (1945) Extinct and vanishing mammals of the old world. American Committee for International Wildlife Protection, New York
Head L (2000) Tasmanian tiger: RIP. Sydney Morning Herald, 15 May. http://www.smh.com.au/articles/2002/09/25/103273420957.html. Accessed 23 Aug 2004
Hebsgaard MB, Phillips MJ, Willerslev E (2005) Geologically ancient DNA: fact or artifact. Trends Microbiol 13(5):212–220
Higuchi R, Bowman B, Freiberger M, Ryder OA, Wilson AC (1984) DNA sequences from the quagga, an extinct member of the horse family. Nature 312(5991):282–284
Hofkin BV, Wright A, Altenbach J, Rassman K, Snell HM et al (2003) Ancient DNA gives green light to Galapagos L and Iguana Repatriation. Conservat Genet 4(1):105–108
Hopkins A (2000) Rebirth of the Tasmanian tiger attempted. The Globe and Mail, 29 August
Jeffreys A (1984) Raising the dead and buried. Nature 312(5991):198
Keen P (2006) The balloonomania: science and spectacle in 1780s England. Eighteenth-Century Studies 39(2):507–535
Kezwer G (1999) Australian scientist proposes recipe for cloning extinct tiger. Canadian Med Assoc J 161(6):680.
Kuhn T (1962) The structure of scientific revolutions. University of Chicago Press, Chicago
Lewontin R (1991) The doctrine of DNA: biology as ideology. Penguin Books, New York
Long Now Foundation (2013) http://longnow.org/revive/. Accessed 13 May 2014
Mattill J (1984) Our shaggy elephant. Technol Rev 87:4
Melville J (2005) Disappearing dragons. Australian Academy of Science Newsletter 62(April-July):5
Meyer A (2005) Hunting the double helix: how DNA is solving the puzzles of the past. Allen & Unwin, New York
Miller JA (1984) Gene samples from an extinct animal cloned. Sci News 125(23):356
Mooney N (2002) Resurrecting the Tassie tiger sounds exotic but let's first save what's left. Sydney Morning Herald, 31 May. http://www.smh.com.au/articles/2002/05/30/1022569815123.html. Accessed 28 June 2010
Nicholls H (2005) Ancient DNA comes of age. PLoS Biol 3(2):0192–0196. http://www.plosbiology.org/article/info%3Adoi%2F10.1371%2Fjournal.pbio.0030056. Accessed 13 May 2014
Olivetto C (2007) The spectacle of science aloft. J Sci Commun 6(2):1–6
Onstalet E (1890) The dog-headed possum. Scientific American LXII(7):105
Owen D (2004) Tasmanian tiger: the tragic tale of how the world lost its most mysterious predator. The Johns Hopkins University Press, Baltimore
Pääbo S (1985a) Preservation of DNA in ancient Egyptian mummies. J Archeol Sci 12(6):411–417
Pääbo S (1985b) Molecular cloning of ancient Egyptian mummy DNA. Nature 314(6012):644–645
Pääbo S, Poinar H, Serre D, Jaenicker-Despres V, Helber J, Rohland N, Kuch M, Krause J, Vigilant L, Hofreiter M (2004) Genetic analysis from ancient DNA. Annu Rev Genet 38:645–679
Paddle R (2000) The last Tasmanian tiger: the history and extinction of the thylacine. Cambridge University Press, Cambridge
Penney D, Wadsworth C, Fox G, Kennedy SL, Preziosi RF, Brown T (2013) Absence of ancient DNA in sub-fossil insect inclusions preserved in 'anthropocene' Colombian copal. PLOS One 8(9):e73150
Pennisi E (2005) Reading ancient DNA the community way. Science 308(5727):1401Rivera SC (2008) Metaphors of DNA: a review of the popularisation processes. Pub Underst Sci 7(1)
Rosenbaum HC, Brownwell RL, Brown MW, Schaeft C, Portuay V et al (2000) World-wide genetic differentiation of Eubalaena: questioning the number of right whale species. Mol Ecol 9:1793–1802
Saunders R and Saunders G (2003) A man for all ages. The Skeptic Autumn. 14–17
Schmeck HM (1985) Intact genetic material extracted from an ancient Egyptian mummy. New York Times (16 April). http://www.nytimes.com/1985/04/16/science/intact-genetic-material-extracted-from-an-ancient-egyptian-mummy.html. Accessed 1 Dec 2013

Sommer M (2009) The lost world as laboratory: the politics of evolution between and fiction in the early decades of twentieth century America. Configurations 15:299–329
Squires N (2004) Scientists lobby for reserve for future Tasmanian tiger clone. South China Morning Post 26 March. http://www.scmp.com/article/449690/scientists-lobby-reserve-future-tasmanian-tiger-clone. Accessed 2 September 2014
Sydney Morning Herald (2001) Extinct for the time being, 24 November. http://www.smh.com.au/articles/2002/09/25/1032734208957.html. Accessed 23 Aug 2004
Sykes B (1991) The past comes alive. Nature 352:381–382
Taggart S (2000) Aussies roaring on DNA cloning. Wired.com, 5 May. http://archive.wired.com/science/discoveries/news/2000/05/36117. Accessed 13 May 2014
Taggart S (2002) Will Tasmanian tiger clone work. Wired.com, 10 June. http://www.wired.com/science/discoveries/news/2002/06/52959. Accessed 27 May 2010
Thacker E (2003) Black magic, biotech & dark markets. In: Sarai reader (ed) Shaping Technologies, pp 134–143. http://preview.sarai.net/journal/reader3.html. Accessed 12 May 2014
Wayne RK, Leonard JA, Cooper A (1999) Full of sound and fury: the recent history of ancient DNA. Ann Rev Ecol Syst 30:457–477
Webb S (1999) Thylacine cloning is big time dreamtime. Australas Sci 20(8):19–21
Williams R (2001) Radio national interview with professor Alan Cooper and professor Mike Archer, 17 November. http://www.abc.net.au/radionational/programs/scienceshow/tasmanian-tiger/3496020#transcript. Accessed 13 May 2014
Wilmut I, Campbell K, Tudge C (2001) The second creation: dolly and the age of biological control. Harvard University Press, Cambridge
Wynne B (2008) Elephants in the room where publics encounter science: a response to Darrin Durant. Pub Underst Sci 17:21–33

Chapter 6
Bio-Imaginaries: Bringing Back the Woolly Mammoth

Abstract This chapter analyzes the social and cultural significance of recent efforts to sequence the genomes of long-extinct species, focusing on the debate about whether or not it will become possible to bring back the woolly mammoth (*Mammuthus primigenius)*. I argue that the idea of cloning a woolly mammoth is a socio-technical imaginary that embodies our fear of the present environmental crisis and our desire to create the future through biotechnological innovation. Ancient DNA analysis and the sequencing of ancient genomes continue to reveal information about deep time and to increase our knowledge of climate change, human migration and species evolution. Yet despite ongoing efforts by many practitioners to focus on these important but normal scientific developments, woolly mammoths keep popping up lately in odd places such as T.E.D. conferences, I-Max documentaries and newspaper articles. This chapter begins in the Smithsonian Museum's Hall of Extinct Monsters, where the mysteries of deep time first became tangible to a mass audience. The following sections consider the progress of woolly mammoth genomic research since the 1980s and the way in which science and science fiction converge and collide in media representations of palaeogenomics. The book concludes with a brief introduction to synthetic biology, a recent technological development that, some proponents say, may provide the skeleton key that will finally unlock the doors to lost worlds.

> *It seems to be the fate of man to seek all his consolations in futurity. The time present is seldom able to fill desire or imagination with immediate enjoyment, and we are forced to supply its deficiencies by recollection or anticipation.*
>
> —Samuel Johnson (1752)

6.1 Entering the Hall of Extinct Monsters

The Smithsonian Institution's National Museum of Natural History in Washington, D.C., today houses an unrivaled collection of 46 million fossils. Dinosaur Hall, one of the Museum's most enduringly popular exhibits, originally had the decidedly more glamorous name "Hall of Extinct Monsters" (Fig. 6.1).

Established in 1910, the Hall of Extinct Monsters introduced eager spectators to some tangible relics of deep time. Though not everyone believed in the veracity of the skeletons of dinosaurs, mammoths and mastodons on display, for many observers the fossils provided unequivocal proof that Charles Darwin had been right. In 1897,

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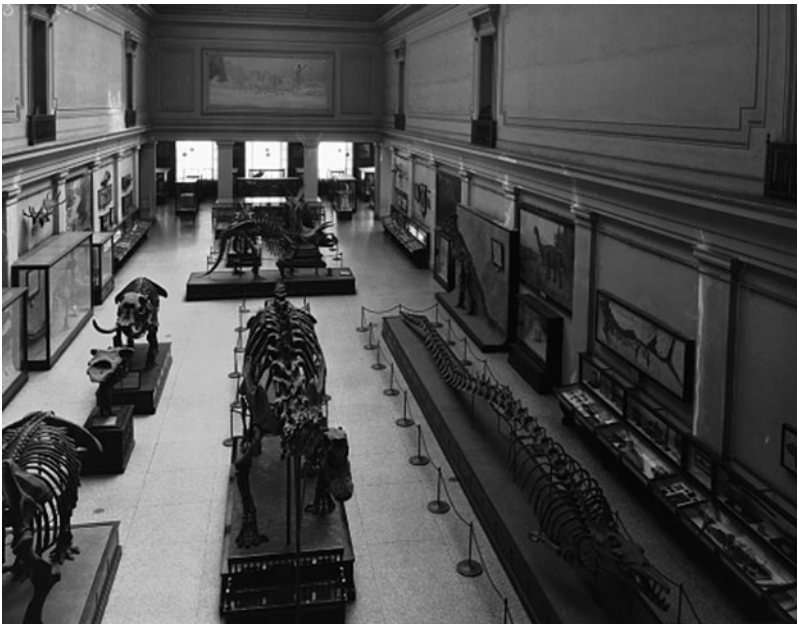

Fig. 6.1 Hall of Extinct Monsters, National Museum of Natural History, 1930s. Smithsonian Institution Archives, 33835-C or MNH33835-C, http://www.si.edu

H. N. Hutchinson (1897) published a charming book entitled *Extinct Monsters: A Popular Account of Some of the Larger Forms of Ancient Animal Life* which teems with flying dragons, giant sloths, armadillos and dinosaurs. He argued that palaeontology was essentially founded on the study of the mammoth, dating to the moment that Georges Cuvier realized that the remains he identified in the early nineteenth century could not possibly have belonged to any extant elephant species. A century later, the bones of mammoths and mastodons also convinced a sizeable public audience that one of God's creatures could indeed go extinct (Conniff 2010). The popular image of the woolly mammoth (distinct from the Columbian mammoth native to the western portion of the United States during the Pleistocene) dovetailed with the rise of mass print media, modern science and the highly publicized British Discovery Expedition to Antarctica (1901–1904). Alongside mummies and mastodons, the mammoth readily became a prime site for the construction of new scientific knowledge.

In an article that compares the coterminous work of author Edgar Rice Burroughs (the creator of Tarzan) and naturalist Henry Fairfield Osborn (president of the American Museum of Natural History), Marianne Sommer argues that both men encouraged spectators to engage with science by grounding the lost worlds of their novels and displays, respectively, in a certain degree of *vraissemblance* or simulated reality. In order to bring the past to life, both used narrative techniques that suspended the spectator's disbelief, creating "windows into the human deep past [that] were meant to educate the public through entertainment" (Sommer 2009,

p. 299). Similarly, Margaret Murray (1863–1963), the English Egyptologist and folklorist, often presented her scientific work to the public through dramatic displays of mummy unwrapping, a practice soon followed by other anthropologists. Kathleen Sheppard notes that the "unwrappings as a practice have shifted often between public spectacles which displayed objectified exotic artifacts and scientific investigations which sought to reveal medical and historical information" (Sheppard 2012, p. 525). Representations of the woolly mammoth also proved a powerful and reliably popular trope through which to communicate new scientific findings about deep time, about a pre-historical past that long predated Biblical accounts of the creation of the world. Indeed, mammoths, perhaps the ultimate charismatic megafauna, quickly proved capable of carrying not only scientific but also cultural weight. Like mummies, the mammoths who cavorted through early media reports on ancient DNA analysis in the mid-1980s had proven themselves effective emissaries, having already been entertaining paying audiences for at least a century. From the moment it walked out of the Ice Age and onto the world stage, the mammoth has been pulled incessantly between the demands of science and the lure of spectacle, with spectacle usually winning.

In order to analyze the social and cultural significance of recent efforts to sequence the genomes of long-extinct species, this chapter focuses on the debate about whether or not it will become possible to bring back the woolly mammoth (*Mammuthus primigenius*). I argue that the idea of cloning a woolly mammoth is a socio-technical imaginary that embodies our fear of the present environmental crisis and our desire to save and create the future through biotechnological innovation. Ancient DNA analysis and the sequencing of ancient genomes continue to reveal information about deep time and to increase our knowledge of climate change, human migration and species evolution. Yet despite ongoing efforts by many practitioners to focus on these important but normal scientific developments, woolly mammoths keep popping up lately in odd places such as T.E.D. conferences, I-Max documentaries and newspaper articles. The next section evaluates the public reception of woolly mammoth genomic research since the 1980s, emphasizing the way in which science and science fiction converge and collide in media representations of palaeogenomics. It then explores the reasons why the woolly mammoth has become the icon of de-extinction and the symbol of our dreams about the restored future. The book concludes with a brief introduction to synthetic biology, a recent technological development that, proponents say, may provide the skeleton key to unlocking lost worlds.

6.2 How to Resurrect a Woolly Mammoth

Woolly mammoths went extinct approximately 11,000 years ago in the late Pleistocene (though a tiny remnant population endured on Russia's Wrangel Island until approximately 2000 B.C.). We've been dreaming of them ever since. Ancient cave paintings discovered in France in the twentieth century depict early humans alongside the creatures. This juxtaposition of man and mammoth probably helps to explain the strange fascination the species continues to inspire in our culture. It took a lot of

imagination and some highly sophisticated computer-generated imagery to put humans alongside the dinosaurs in the popular film *Jurassic Park* (1993) and its three sequels. Fans of those films didn't suspend disbelief so much as they just ignored it. Woolly mammoths, though, exist in that fuzzy liminal realm between fact and fantasy, between science and science fiction, because we can dream ourselves into its landscape if we try hard enough. The woolly mammoth may be ancient, according to the way in which we measure time, but it is also an oddly modern mammal if by modern we refer to the science that made it real to Western audiences long separated from the Pleistocene.

In this scientific sense, the mammoth has been with us from the start and has often inspired intense emotions. In the early 1700s, the Irish collector Hans Sloan began collecting the fossilized teeth and tusks of Siberian woolly mammoths, anticipating the scientific findings of Georges Cuvier in the 1790s. Thomas Jefferson was obsessed with the notion that a Columbian mammoth might still exist in the remote United States and displayed his impressive collection of mammoth fossils in the entryway to Monticello. Several decades before *Technology Review*'s mammoth hoax about ancient DNA and the birth of *elephas pseudotherius* (discussed in Chap. 5), the popular *McClure's Magazine* ran a story in October 1899 titled "The Killing of the Mammoth." Though clearly labeled in the table of contents as fiction, the story about a modern adventurer who hunts down and kills the last surviving mammoth in the Alaskan wilderness incensed so many readers, many of whom wrote to the Smithsonian Institution to express their outrage, that the magazine had to publish a retraction (Bessie 1980). Today, debate continues to rage just as it did in the late nineteenth century as to the reasons why the woolly mammoth went extinct: was it primarily the fault of climate change, a disease outbreak, or the innovative new spear tip technology that the Clovis hunters brought to North America? This scientific contretemps has gained a new public urgency in light of our concerns about anthropogenic climate change though, in an ironic twist, the recent proliferation of mammoth carcass discoveries that help to propel ancient DNA analysis and increase our knowledge of long-term climatic change is in large part due to the thawing of permafrost in this warming world. Always adaptable, the woolly mammoth is both the Titan of the Ice Age, as a recent I-Max documentary puts it, and also the new symbol of an environment rapidly reaching tipping points beyond which human beings and other species may not be able to adjust. Whether we look to the past, the present or the future, mammoths are, in the words of palaeontologist Larry Agenbroad, "still very much with us" (Salkever 1999).

6.2.1 Raising the Mammoth

The ancient urge to represent the woolly mammoth in cave drawings has morphed into the desire to recreate the mammoth in the early twenty-first century. From the moment Dolly the Sheep debuted in 1997 to take us into the new age of reproductive cloning, the idea that modern science will find a way to bring back these extinct creatures

has entranced the mass media, the public and even many scientists. The Thylacine Cloning Project received international media attention, as noted in chapter 5, but that species' story is largely the story of Australia. The woolly mammoth's appeal seems to be multinational as scientists in the United States, Japan, South Korea and Russia debate whether or not a resurrected mammoth is or will become feasible and new developments in mammoth research appear in the most prestigious media outlets. Japanese scientists Kazufumi Goto and Shoji Okutsu had declared even before Dolly became famous that they hoped to find well-preserved DNA in the sperm of a frozen mammoth and then use it to inject the eggs of a surrogate Asian elephant. Over several generations of selective breeding, the scientists believed they could eventually produce a specimen that was essentially a mammoth (Associated Press 1996). The Mammoth Creation Project, based in Japan today, continues to focus on research related to potential mammoth-elephant hybrids and mammoth cloning.

In 1999, the discovery of a specimen named Jarkov (in honor of the family name of the young Dolgan reindeer herder who originally found the tusks in 1997 and led researchers to the carcass) genereated intense media speculation about cloning and headlines such as "Can Cloning Restore Pitter Patter of Mammoth Feet" (The Palm Beach Post), "Goodbye Dolly, Hello Hairy, Prehistoric Mammoth Clone" (The Sunday Herald), "Scientists Hope to Clone Pachyderm" (The Washington Times), and "Bringing Back the Beast" (The Moscow Times). The Jarkov specimen lent itself to such publicity both because of new interest in the emerging field of ancient DNA analysis and the fact that it was, though 20,000 years old, virtually intact (one of only 12 such specimens discovered in over 200 years). French polar explorer Bernard Buigues and his team extracted the remains in a 23-ton block of ice, flying it by helicopter to an ice cave in the town of Taimyr, Siberia for analysis. Even the austere *New York Times* toyed with the idea of Jarkov cloning, though it was quick to cite ethicist Greg Pence who noted that " 'you need live nuclei and live eggs, plus a host mammoth mother to gestate the fetus. Because none of these are available, "Jurassic Park" to the contrary, it won't succeed' " (New York Times 1999). The Discovery Channel, confounding the line between science and spectacle in this case, made two dramatic documentaries about the Jarkov research: Raising the Mammoth (2000) and Land of the Mammoth (2000).

In 2001, Alan Cooper and his team mapped the first complete mitochondrial sequence of an extinct species, the New Zealand moa (Cooper et al.2001) while in 2005, scholars sequenced substantial amounts of the nuclear genome of two cave bears that had been extinct for 40,000 years (Noonan et al. 2005). The Mammoth Genome Project (Pennsylvania State University), under the leadership of Dr. Stephen C. Schuster and Dr. Webb Miller, sequenced the largest amount of nuclear DNA from an extinct species to date when in 2008 it announced that it had mapped approximately 80 % of the woolly mammoth genome (approximately 4.7 billion nucleotides). Schuster and Miller focused on the scientific merits of their research, which gained international media attention, stating that "in general, our work shows that it is possible to open a window to the past and study animals that are long gone at the same level of genetic detail as when examining modern species. The lessons

being learned from studying extinct species can help us understand the processes that are driving today's endangered species toward possible extinction (Mammoth Genome Project n.d.). Other scientists weighed in to applaud the legitimate scientific milestone achieved by the Mammoth Genome Project, but cautioned that cloning a woolly mammoth was, in the words of Dr. Michael Bunce, Head of Ancient DNA Laboratory at Murdoch University, " 'still a pipe-dream' " (Australian Science Media Centre 2008). Dr. Jeremy Austin, Deputy Director of the Australian Centre for Ancient DNA at The University of Adelaide, also praised the work, but noted that the genome, due to the extreme age of the DNA sampled, was inevitably full of errors and that a genome sequence does not magically equate to a living organism. He likened cloning a woolly mammoth in this case to " 'trying to build a car with only 80 % of the parts and knowing that some of the parts are already broken' " (Australian Media Centre 2008).

6.2.2 Pleistocene Dreams

Naomi Oreskes (2004) argues that "if we feel that a policy question deserves to be informed by scientific knowledge, then we have no choice but to ask, what is the consensus of experts on this matter" (p. 3723)? With respect to the far frontiers of cloning extinct species, however, the consensus that it is impossible seems to be fraying at the edges, leaving the public and policymakers in a quandary. Uncertainty about the research and its implications renders the demarcation between science and science fiction more difficult to police than in the past, particularly in popular forms which have already been leveraging the commercial advantage of resuscitated mammoths for years. Michael Hofreiter, for example, responded to media hyperbole around Schuster and Miller's 2008 work by stating unequivocally in one article that "the mammoth will never roam the earth again," though he conceded in *National Geographic* that " 'theoretically it's not completely out of the question, but I see so many problems that I can't imagine it would ever work' " (Carroll 2008). Even *Nature* ran an article in response to publication of the draft woolly mammoth genome which reminded readers, per extinct species cloning, that "the fact that just 15 years ago cloning mammals was confidently ruled out by man as being impractical should give people pause before saying any such thing is impossible" (Nicholls 2008).

As we enter the new millennium, the qualifiers and caveats that characterize scientific discussion of the woolly mammoth genome and the related issue of mammoth cloning seems different in kind, less certain and more anticipatory, when compared to earlier speculation about thylacine cloning a decade ago. In the ten years since the Australian Museum's thylacine project ended, progress in fields such as synthetic biology has been rapid and disruptive. As Jean Baudrillard observed, "science fiction... is no longer anywhere, and it is everywhere, in the circulation of models, here and now, in the very principle of the surrounding simulation" (Baudrillard 1983). In other words, when a scientist as respected as Professor George Church, Harvard synthetic biologist, is featured in an article posted on the Revive and Restore website

(http://longnow.org/revive/) leading a project premised on the notion that, at the very least, a hybrid and resuscitated mammoth is now scientifically possible (Koebler 2014), the public and policymakers cannot be blamed for beginning to dream that biotechnology will stop and even reverse extinction. In 2014, the discovery of a 40,000 year old mammoth carcass freeze-dried in permafrost on Maya Lyakhovsky Island, Russia, led Radik Khayrullin, vice president of the Russian Association of Mammoth Anthropologists, to declare on behalf of a multinational team including American, Danish, British, Moldovian and South Korean scientists that " 'the data we are about to receive will give us a high chance to clone the mammoth' " (Jonas 2014).

The practical reason for the palaeogenomic focus on woolly mammoth research stems from the facts that permafrost is nature's freezer and that there were multitudes of mammoths that became trapped in ice centuries ago. Yet there is a cultural reason and resonance as well in the use of this magnificent species. Elta Smith argues that "imaginaries... are normatively loaded visions not only of what should be done 'in the world' but also how it should be undertaken and why" (Smith 2009, p. 462). The woolly mammoth represents both the Ice Age and the Palaeo-Future. As idea and artifact, it can be enrolled to evoke the facts of the deep past but also the promise of the deep future, that soon-to-be world in which mastodons, moas and giant ground sloths exist again alongside passenger pigeons and Tasmanian tigers. The promissory aspect of biotechnology and human health is now well studied. Even blood, for example, can be understood as "the bearer of a whole range of anticipatory claims about future therapeutic possibilities... expectation and hope" (Brown and Kraft 2006, p. 330). However, we are only just beginning to recognize the implications of promissory wildernesses and to grapple with the way in which advanced biotechnology seems to reshape the natures we can envision. In this new era, the woolly mammoth and its thawed blood becomes a promissory object, the idea of a cloned mammoth a way to ground and translate new technologies that seems to offer a way around the confrontation with disaster that has animated environmental activism for decades. It seems to provide the proof that all life processes can "be 'reverse engineered' and then reconstructed in the lab and modified so that they unfold in different ways" (Rose 2001, p. 16). Put another way, as Henry Nicholls concludes, "By 2059, who knows what may have returned, rebooted, to walk the Earth" Nicholls 2008, p. 314.

6.3 Engineering Life: Synthetic Biology

The potential power of the new science of synthetic biology underwrites visions of reviving and restoring extinct species, in line with DeSalle and Amato's observation (2009) that "crisis disciplines often see periods of expansion of the toolbox used to address dilemmas posed by the forces causing the crises" (p. 3). Synthetic biology is an emerging field through which scientists hope to be able to design and build *de novo* organisms. It relies upon the development of standardized and interchangeable biological units known as bio-bricks and is predicted to have crucial applications

in such areas as alternative fuels and energy security, environmental clean-up, and human health. Synthetic biology raises important governance issues with respect to public mistrust of techno-science, its potential use in new forms of biological terrorism, and the risk of environmental contamination by novel and self-replicating organisms. It also has significant implications for conservation genomics and the attempt to bring back an extinct species

The inaugural international meeting (Synthetic Biology 1.0) of the synthetic biology scientific community took place in Cambridge, MA in June 2004. Synthetic biology embodies a scientific drive to understand, control and regularize biological processes. In October 2005, for example, the European Commission (EC) released a Reference Document on Synthetic Biology. It asserts that synthetic biology is "a new way of making things" (EC 2005, p. 4), referring to synthetic biology as the foundation for an entirely new approach to harnessing biological systems to manufacture products and processes". Extending the engineering metaphor, the reference document concludes that synthetic biology "opens up the possibility of manipulating living systems and their component parts in a rational way, akin to the way in which engineers design new machines, cars or planes" (EC 2005, p. 4). Key to this systematic approach—and what distinguishes it from the earlier tools of rDNA or genetic modification—is the use of bio-bricks to build "engineered parts or systems [that] show a tangible and useful standardized function or functionality with substantially different characteristics from natural functions" (EC 2005, p. 5). In essence, bio-bricks are to biology what the standardization of electronic circuits was to the global information technology industry in the 1970s. To build a global synthetic biology commercial sector requires a literal cataloguing of standard biological units that can be manipulated and fitted to suit each new product/application, while remaining seamless and interchangeable at the most basic level. In 2004, the Synthetic Biology Working Group at M.I.T. established a Registry of Standard Biological Parts, an initial stage in what Tucker and Zilinskas describe as "perhaps the most ambitious subfield of synthetic biology. . . a 'tool box' of standardized genetic parts with known performance characteristics" (2006, p. 29). Synthetic biology—while in an early stage—seeks not only to develop standardized bio-bricks, but also to enable the creation of hybrid, and even entirely novel, organisms in the lab. As Tucker and Zilinskas (2006) argue, "synthetic biology is another transformative innovation that will make it possible to build living machines from off-the-shelf chemical ingredients, employing many of the same strategies that electrical engineers use to make computer chips" (Tucker and Zilinskas 2006, p. 25).

6.4 In Search of Lost Worlds

The dream of conquering death with technology haunts the twentieth century. Leonid Krasin (1870–1926), the man put in charge of entombing Vladimir Lenin and a follower of the Russian philosopher and mystic Nikolai Fyodorov (1829–1903), felt " 'certain that the time will come when science will become all powerful, that it will

be able to recreate a deceased organism. . . . The time will come when one will be able to use the elements of a person's life to recreate the physical person [and] resurrect great historical figures' " (Tumarkin 1997). In the 1930s, the brothers Lutz and Heinz Heck, directors of the Berlin Zoo and Munich Zoo, respectively, started a genetic experiment to restore the original auroch. They hoped to recreate the auroch, which had gone extinct in the wild in Poland in 1627, by a process of artificial selection in which successive generations of the species' descendants were interbred into order to "breed back" to the original genetic blueprint. Julius Caesar had commented on the impressive size of the breed in ancient Rome and the auroch exerted a particular fascination for high-ranking officials in the Nazi Party, prompting Hermann Goering to co-opt the Hecks' research during World War II. Michael Wang notes that "the *idea* of the aurochs was precisely that of a lost genetic unity," while its reintroduction "into the German landscape was part of a larger project of constructing a national identity based on mythic foundations" (Wang 2012). Michael Heck continued to work as an agricultural scientist during the Cold War. (Today's Heck's cattle can be traced to his work and to the cattle that survived the bombing of Munich at the end of the War). Indeed, he ultimately made significant contributions to the scientific study of breeding and extinction, arguing in 1951 that "no animal is utterly exterminated as long as some of its hereditary factors remain" (Heck 1951, p. 119). His dream of the lost auroch endures today. Stichtung Taurus, a Dutch environmental organization, is leading a project to breed back authentic aurochs and hopes to repopulate Holland's natural reserves with recreated wild cattle. The project manager, Henri Kerkdijk, believes that "the auroch was part of an ecosystem. If you want to recreate the flora of the ecosystem, you also have to recreate the fauna" (Faris 2010).

Appropriately, the same 1963 issue of *Life International* that announced to the world the discovery of the DNA double helix also contained an article entitled "Africa's Animals in Peril." Illustrated with disturbing images of both stuffed tiger heads piled up in a Nairobi shop window and a poacher's cache of elephant and zebra carcasses, the article lamented that even in central Africa, which seemed at the time to be the last refuge for wild animals in the modern world, "the threat to wildlife has now become acute" (Life International 1963, p. 62). As previously discussed, the early 1970s witnessed a renaissance of organized environmental action at the same time that a new sense of pending catastrophe began to pervade the work of both activists and scientists. It also witnessed the parallel emergence of the biodiversity crisis and major advances in genetic engineering and recombinant DNA.

These twin themes of scientific progress and environmental catastrophe reverberate to this day and are now joined by the promissory vision of de-extinction, which seems to offer some measure of hope in a field previously characterized by doom. Many scientists and conservationists deplore de-extinction as false hope which is also dangerous because it encourages a cavalier attitude to species preservation and habitat protection. Yet as Kent Redford of the Wildlife Conservation Society argues, " 'my chosen field of conservation started off with a conviction that it is a crisis discipline, and you can only get people's attention by pointing out what is wrong and the terrible things that we're doing to the natural world. I think that after thirty years of that, people have stopped listening to us. I think the lesson should be that hope

is the answer, and that hope will get people's attention'" (Fisher Scientific 2013, p. 32). De-extinction, an idea developed and supported by major figures in both the corporate and public research sectors, encourages us to place our faith in the ability of technoscience not only to save endangered species but to restore and revive extinct ones.

We may realize that "the past is littered with failed futures (Brown and Michael 2003, p. 7), but both our belief in science and our ability to dream have proven remarkably resilient. Of course, that may be because, in this instance, we cannot allow this particular future to fail. Whether or not woolly mammoths join us in the palaeo-future remains to be seen, though I am among those willing to wager that, at the very least, a mammophant one day will. In the meantime, for all of the ethical and scientific problems inherent in doing so, and while acknowledging the fact that saving habitat is absolutely essential to the future of any wilderness worthy of the name, we must continue to dream of the end of extinction.

References

Associated Press (1996) Shades of Jurassic park: Researchers seek to re-create woolly mammoth. id-ed8e7847c1679e157ae7d131615bac84. Accessed 2 September 2014

Australian Media Centre (2008) Woolly mammoth DNA decoded, experts comment. http://www.smc.org.au/2008/11/rapid-roundup-woolly-mammoth-dna-decoded-nature-experts-comment/. Accessed 25 June 2014

Baudrillard J (1983) Simulations. University of Michigan Press, Ann Arbor

Bessie NL (1980) The great mammoth hoax. Alaska J 10(4):10–16. http://www.museumofhoaxes.com/lastmammoth.html. Accessed 25 June 2014

Brown N, Kraft A (2006) Blood ties: banking the stem cell promise. Techno Anal Strateg Manage 18(3):313–327

Brown N, Michael M (2003) A sociology of expectations: retrospecting prospects and prospecting retrospects. Technol Anal Strateg Manage 15(1):3–18

Carroll R (2008) Mammoth genome de-coded: clones on the way? National Geographic, 19 November. http://news.nationalgeographic.com/news/2008/11/081119-mammoth-DNA.html. Accessed 25 June 2014

Conniff R (2010) Mammoths and mastodons: all American monsters. Smithsonian Magazine (April): http://www.smithsonianmag.com/science-nature/mammoths-and-mastodons-all-american-monsters-8898672/?no-ist. Accessed 25 June 2014

Cooper A et al. (2001) Complete mitochondrial genome sequences of two extinct moas clarify ratite evolution. Nature 409:704–707

DeSalle R, Amato G (2009) The expansion of conservation genetics. In: Amato G et al. (eds) Conservation genetics in the age of genomics. Columbia University Press, New York, pp 3–24

Faris S (2010) Breeding ancient cattle back from extinction. Time, 12 February. http://content.time.com/time/health/article/0,8599,1961918,00.html. Accessed 30 June 2014

Fischer Scientific (2013) Project de-extinction: exploring pathways for bringing back lost species. LabReporter 32–33. http://filestore.fishersci.com/cmsassets/downloads/segment/Scientific/pdf/LabReporter/project-de-extinction.pdf. Accessed 25 June 2014

Heck H (1951) The breeding-back of the aurochs. Oryx 1(3):117–122

Hutchinson HN (1897) Extinct monsters: a popular account of some of the larger forms of animal life. http://www.gutenberg.org/files/42584/42584-h/42584-h.htm. Accessed 25 June 2014

Jonas G (2014) Woolly mammoth DNA to be cloned, then joined with elephant DNA to create a new creature. International Science Times, 13 March. http://www.isciencetimes.com/articles/6946/20140313/woolly-mammoth-dna-cloning-elephant-clone.htm. Accessed 25 June 2014

Koebler J (2014) The plan to turn elephants into woolly mammoths is already underway. Motherboard, 21 May. http://motherboard.vice.com/en_us/read/the-plan-to-turn-elephants-into-woolly-mammoths-is-already-underway. Accessed 25 June 2014

Mammoth Genome Project (n.d.) Lessons from the mammoth genome. http://mammoth.psu.edu/. Accessed 25 June 2014

New York Times (1999) Frozen woolly mammoth inspires cloning project. The New York Times, 5 October. http://www.nytimes.com/1999/10/05/science/frozen-woolly-mammoth-inspires-cloning-project.html. Accessed 26 June 2014

Nicholls H (2005) Ancient DNA comes of age. PLOS Biology 3(2):E56

Nicholls H (2008) Darwin 200: letÊ¼s make a mammoth. Nature 456:310–314

Noonan JP et al. (2005) Genomic sequencing of Pleistocene cave bears. Science 309(5734):597–599

Oreskes N (2004) The scientific consensus on climate change. Science 306(5702):1686

Rose N (2001) The politics of life itself. Theory, Culture & Society 18(6):1–30

Salkever A (1999) Scientists play 'Jurassic Park' with mammoths. The Christian Science Monitor 12 October. http://www.csmonitor.com/1999/1012/p1s4.html. Accessed 2 September 2014

Sheppard K (2012) Between spectacle and science: Margaret Murray and the tomb of the two brothers. Science in Context 25(4):525–549

Smith E (2009) Imaginaries of development: the Rockefeller Foundation and rice research. Sci Cult 18(4):461–482

Sommer M (2009) The lost world as laboratory: The politics of evolution between science and fiction in the early decades of twentieth-century America. Configurations 15:299–329

Tucker JB, Zilinskas RA (2006) The promise and perils of synthetic biology. The New Atlantis: http://www.thenewatlantis.com/publications/the-promise-and-perils-of-synthetic-biology Accessed 25 June 2014

Tumarkin N (1997) Lenin lives: The Lenin cult in Soviet Russia. Harvard University Press, Boston

Wang M (2012) Heavy breeding. Cabinet 45 (Spring). http://www.cabinetmagazine.org/issues/45/wang.php Accessed 29 June 2014